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REPORT NO 143

- A MANUAL FOR SITE DEVELOPERS -

Montana Joint Water Resources Research Institute

Montana State University

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PREFACE

The Montana Water Resources Research Center (MWRRC), located on the campus of Montana State University, is responsible for coordination and administration of regional and statewide programs of water resources research and investigation.

Development of water related energy resources, such as small-scale hydroelectric power, is presently underway in Montana and surrounding intermountain states. Estimates of Montana's presently undeveloped hydropower potential range as high as 2000 megawatts, most of which is developable only in the form of small-scale facilities.

In publishing this document, MWRRC shares the position held by the Montana Department of Natural Resources and Conservation and the U. S. Department of Energy that individuals attempting to develop hydropower generation facilities be aware of the complex and technical nature of such an undertaking. It is therefore the purpose of this document to provide a detailed summary of all the major aspects of project development along with encouraging the growth of hydropower as a statewide industry.

ACKNOWLEDGMENTS

The efforts of Dr. William A. Hunt, Director of the Montana University Water Resources Research Center, throughout the duration of this project are gratefully acknowledged. Similarly the contributions made by Mr. David Peterson, Civil Engineering Graduate Student, have been timely and valuable.

Several chapters of this document contain both graphical and text material which has been taken directly from previous hydropower reports and publications. Permission for reproduction of this material was granted by the following individuals and is gratefully acknowledged:

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Ron Ott, Ott Water Engineers, Redding, CA

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Chapter I

INTRODUCTION

This manual has been prepared for individuals who intend to develop small-scale hydropower sites in Montana. Although it is assumed that most small hydro projects* will have a generating potential in the range of about 100 kilowatts to 1 or 2 megawatts, much of the information provided will also apply to sites either above or below this range. The manual also contains information regarding various types of project layouts such as 1) modified existing dams or structures, 2) new dams or diversions, or 3) canals, drop structures or irrigation systems adapted to hydropower production. Both "high" and "low" head facilities are considered; a project, regardless of power generation potential, is considered low head if the gross head is less than 20 m(66 feet).

The major purpose of this manual is to place in the hands of the site developer as much relevant information concerning the development of small hydro projects as is presently possible. Such information includes: 1) engineering data for evaluating feasibility and design, 2) financial information including cost data, power sales and tax incentive information, and 3) licensing and permitting requirements for Montana. A detailed glossary of hydropower terminology has also been provided.

A complete analysis of the feasibility and design of a small hydro system is a complex undertaking. Although information is provided on most of the major phases of project development, this manual will <u>not</u> provide all of the information needed to completely develop a hydropower project. Once the decision has been made to proceed, it is strongly suggested that the developer seek professional advice in the engineering, legal and financial aspects of project development.

DEVELOPING SMALL HYDRO IN MONTANA

Small hydropower development is governed by a variety of technical and nontechnical factors which will be discussed in detail in later chapters. The topics discussed below are intended to provide an overview of the more important processes involved in developing a small hydro project. A flow chart of the hydropower development process is provided

*Projects with generating capacity less than 100 KW are frequently referred to as "Micro-hydro" projects.

in Figure I-1.

Reconnaissance

Once a possible site location has been established, a reconnaissance level study may be carried out. Such a study is intended to develop as much information as possible regarding site potential at minimum cost to the developer. Reconnaissance activities include:

1) Determination of preliminary site location, layout and access.
2) Development of hydrologic data, including a flow-duration curve, for use in determining design power plant capacity and plant capacity factor.
3) Contact with the appropriate utility to determine terms of the power sales agreement. This should be followed by an assessment of costs involved with contract terms and requirements for tie-in with the nearest distribution line.
4) Determination of permit and license requirements for the proposed site as well as the costs involved in permitting process.
5) Solicitation of cost estimates for major system components (turbines, generators, penstock, construction, etc.).

Reconnaissance investigation may suggest modifications to the preliminary site layout and the procedure may need to be repeated for several project alternatives.

Project Economics

A thorough economic analysis of a small hydro project requires obtaining information on costs, power sales, taxation and financing. Detailed discussion of these may be found in appropriate chapters. The major point here is that all aspects of project economics should be completely understood before significant financial commitment is made. Care should be taken to uncover all "hidden costs" which may arise during several stages of project development (i.e. easement costs for crossing state school trust land, equipment and maintenance costs for connecting to an existing power grid, cost of liability insurance for the project, cost for professional services, etc.). It is recommended that the developer carefully review all aspects of project development for possible cost items.

Estimating Costs

The costs involved in developing hydroelectric energy are extremely site specific. Because very few small or micro-hydro facilities have actually been constructed, uncertainty exists regarding several aspects of site development including construction costs and construction methods as well as costs of turbine and other hydraulic and electrical equipment. Since generalized cost statements cannot be made the developer will likely have to solicit estimates directly from engineers, contractors and equipment manufacturers in order to properly assess project costs.

Several reports, which are listed at the conclusion of this chapter, have recently been prepared for use as guidelines for preparation of economic reconnaissance studies for small hydro development. The cost curves and data presented in Figure I-2 may be helpful in gaining a rough estimate of project cost. The figure was obtained from the Colorado hydropower manual titled Water Over the Dam - A Small Scale Hydro Workbook for Colorado,A Small Scale Hydro Workbook for Colorado, (See Reference I-8). As such curves can be easily misused, it is advisable to read the qualifying remarks carefully. Current cost guidelines for individual system components are presented in Figures I-3 through I-13. These curves were developed by Ott Water Engineers of Redding, California (see Reference I-1) and again provide "ball-park" cost estimates only. Curves of this type are useful during the reconnaissance phase of site investigation. However, in assessing project feasibility, actual costs of system components must be obtained from engineers, contractors, and equipment suppliers.

Environmental Effects

It is important for the site developer to determine the specific environmental factors that may influence project development. Some of the more common factors include the following:

1) Conformance with state and federal requirements concerning temporary discharge of pollutants during construction as well as requirements for the proper handling of dredge and fill material
2) Possible effects of water level fluctuations on fish and wildlife habitat both in and downstream from a hydropower impoundment
3) Alterations in water temperature and other water quality parameters

4) Streambank erosion potential

More information regarding important environmental factors may be found in Chapter II "Permitting and Licensing Requirements".

Safety and Liability

There are two items of possible concern to the site developer which have to do with project safety and liability:

1) Individual utilities and cooperatives in Montana may require the developer to carry liability insurance against injury of persons, property, environment, etc. caused by the operation of the facility.
2) FERC Licensing requirements stipulate that the developer must demonstrate safety and structural integrity of the hydropower facility. If the project involves an existing dam then modifications to dam features such as spillway or outlet may be required in addition to installation of turbine generator facilities.

Implications of the above criteria must not be overlooked in the analysis of project benefits and costs.

Operation and Maintenance

Most small hydro installations in the United States are recent projects and comprehensive information on longterm operation and maintenance problems is scarce. The following summary of typical maintenance problems for low-head hydroelectric projects, which was prepared by Tudor Engineering Company (see Reference I-3), lists items which may be important to small hydro projects depending on the type of system installed. Normal maintenance could include weekly inspection of the following items:

- Generator bearing oil levels
- Turbine shaft seal
- Speed increaser oil level
- Trash rack debris or ice accumulation

Annual maintenance items (requiring plant shut down) include:

- Changing or filtering of governor, valve, turbine bearing, speed increaser and generator bearing oil
- Turbine shaft run out test
- Replacing turbine shaft seal packing
- Inspection and weld repair of the runner
- Inspection and repair of wicket gate seal surfaces

- Inspection and replacement of water seals on submerged bearings
- Inspection of turbine shutoff valve seats and shaft packing
- Dielectric test of the transformer and breaker oil
- Washdown of porcelain insulators
- Cleaning of control compartments
- Trip setting test on relays

The extent of annual maintenance repair is influenced by the water quality. Power plants using corrosive water or water containing sand or silt require more maintenance on bearings and flow passageway surfaces.

Tudor Engineering Company also conducted a survey of 160 public utility companies to determine plant operation and maintenance cost data. The results, which appear in Figure I-14, may vary considerably depending on plant size, location, and operation characteristics. Since the time this cost data was developed (1973-1978) there have also been considerable advances in equipment design (especially for small hydro units) resulting in reduced maintenance costs. However, the type of maintenance required as well as the annual cost remains a significant factor in project design.

Project Feasibility

Results of the reconnaissance investigation serve as the basis for deciding whether or not a complete feasibility study is warranted. Assessment of project feasibility usually represents a substantial cost to the developer and includes the following items:

1) Detailed project design
2) Analysis of project benefits and costs
3) Determining ability of project to conform with permitting, licensing and legal requirements.

It is recommended that the professional engineering expertise be sought for the feasibility stage of project development.

FIGURE I-1
GENERALIZED OVERVIEW OF THE PROCESS PRIOR TO CONSTRUCTION OF A HYDROPOWER PROJECT

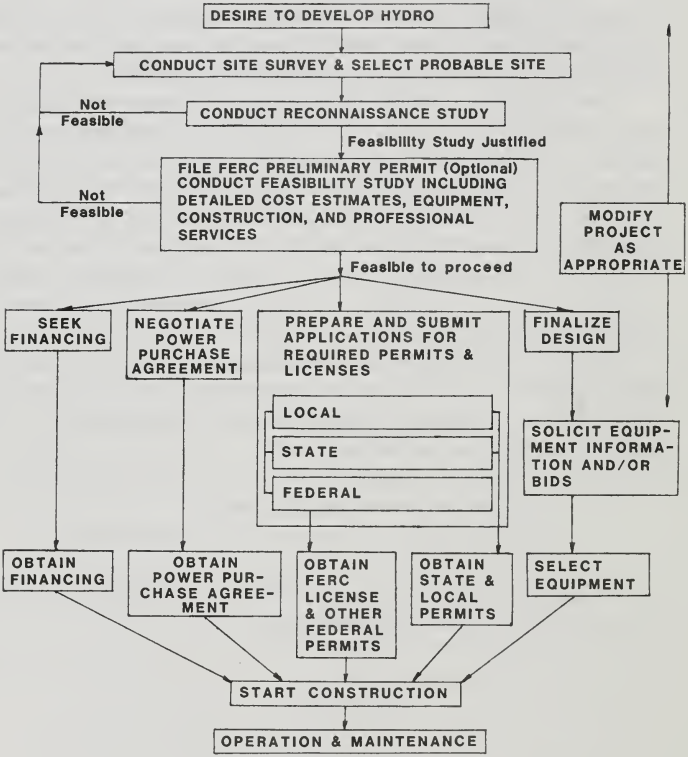
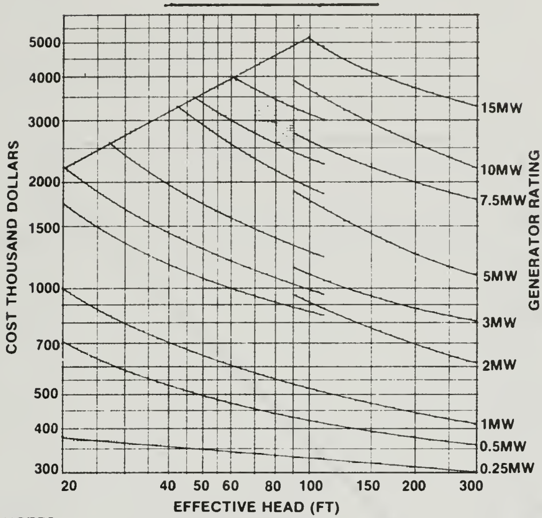


Chart derived from Developing Hydropower in Washington State, June 1981

FIGURE I-2 PROJECT COST



NOTES:

1. Estimated costs are based upon a typical or standardized turbine coupled to a generator either directly or through a speed increaser, depending on the type of turbine used.
2. Costs include turbine/generator and appurtenant equipment, station electric equipment, miscellaneous powerplant equipment, powerhouse, powerhouse excavation, switchyard civil works, an upstream slide gate, and construction and installation.
3. Costs not included are transmission line, penstock, tailrace construction and switchyard equipment.
4. Cost base July 1978.
5. The transition zone occurs as unit types change due to increased head.
6. For a Multiple Unit powerhouse, additional station equipment costs are \$20,000 + \$58,000x(n-1) where n is the total number of units.
7. Data for this figure was obtained from figures and tables in Volumes V and VI.

Source: "Developing A Site," Raymond Cunningham of International Engineering Company, Inc., The Energy Bureau Conference, Washington D.C., April 27-28, 1981, page 4.

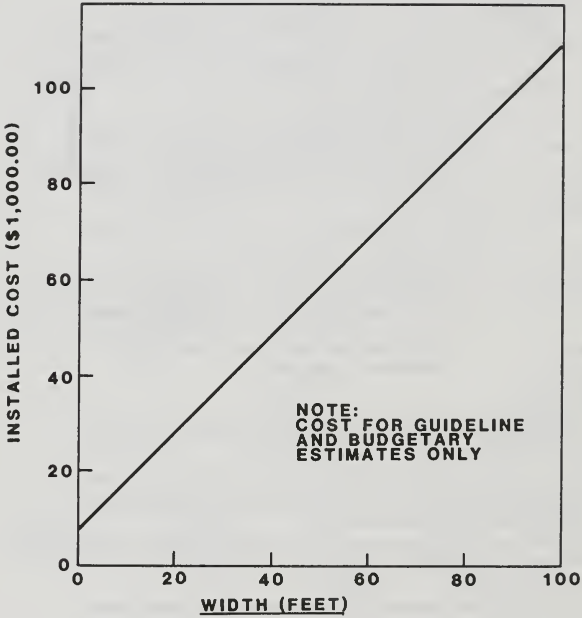


FIGURE I-3
DIVERSION STRUCTURE
(INSTALLED COST)

OTT

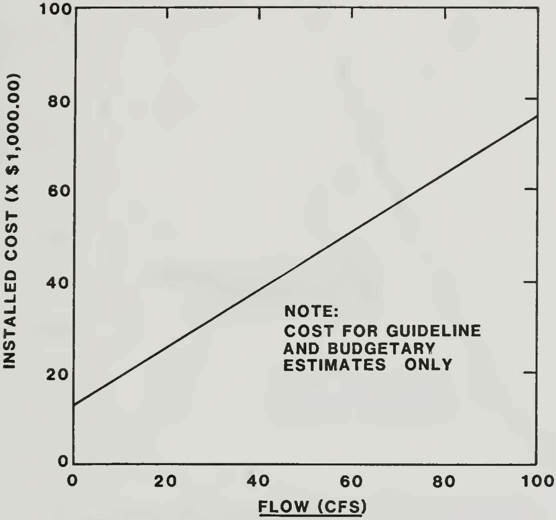


FIGURE I-4
INTAKE STRUCTURE
(INSTALLED COST)

OTT

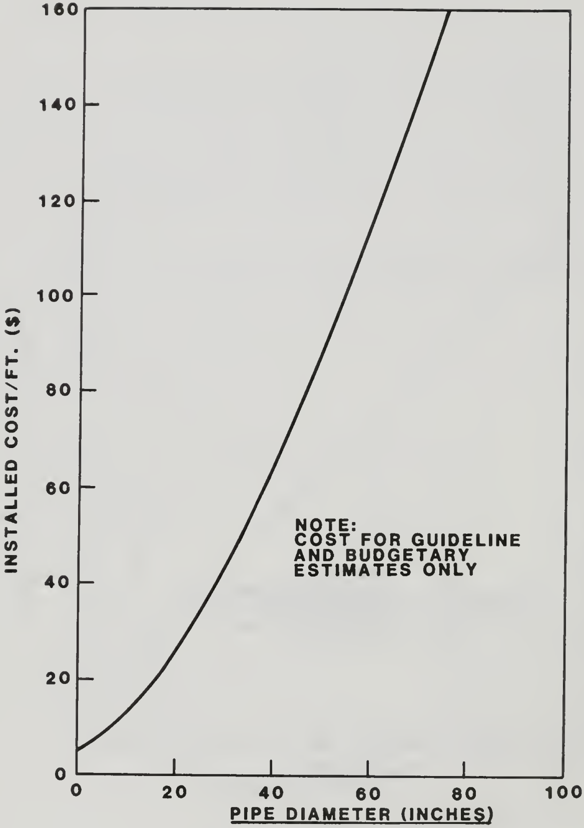


FIGURE I-5
LOW-PRESSURE PIPELINE
(INSTALLED COST)

OTT

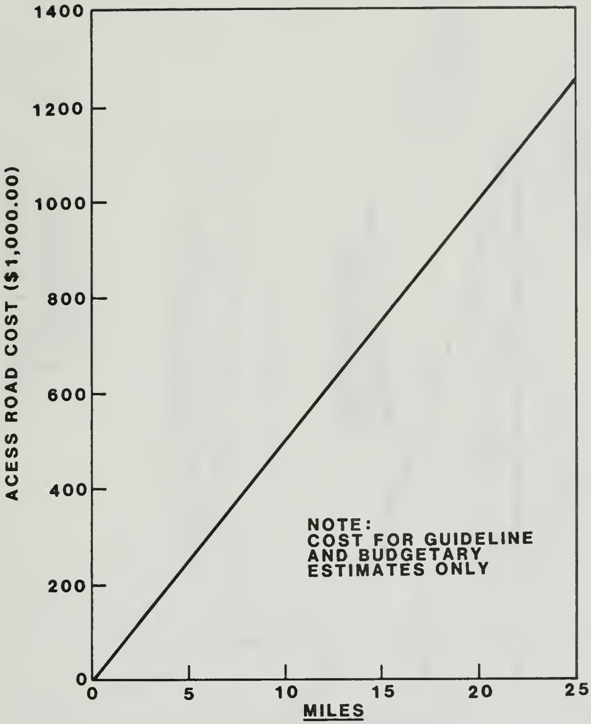


FIGURE I-6
ACCESS ROAD
(INSTALLED COST)

OTT

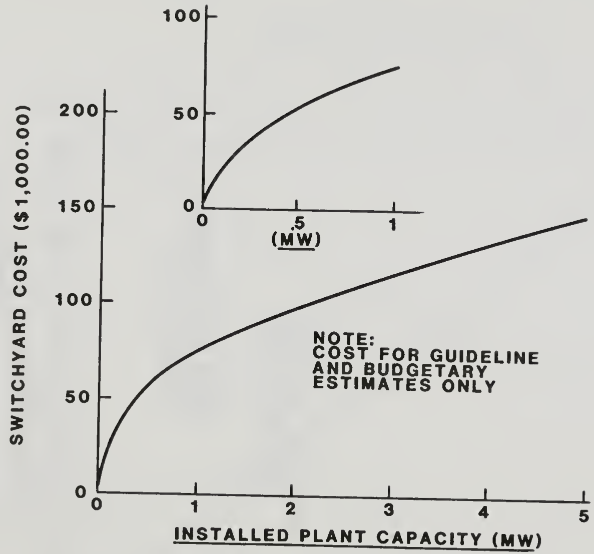


FIGURE I-7
SWITCHYARD
(INSTALLED COST)

OTT

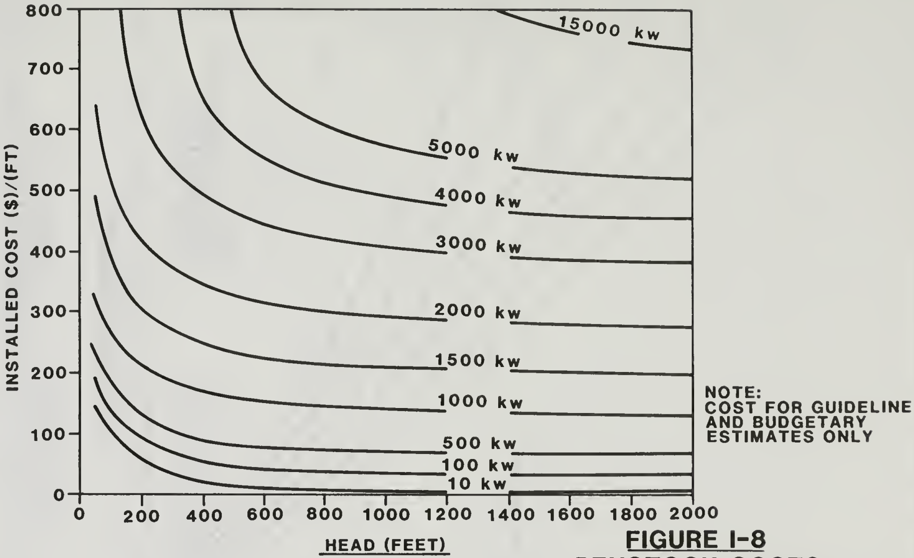


FIGURE I-8
PENSTOCK COSTS
(INSTALLED)

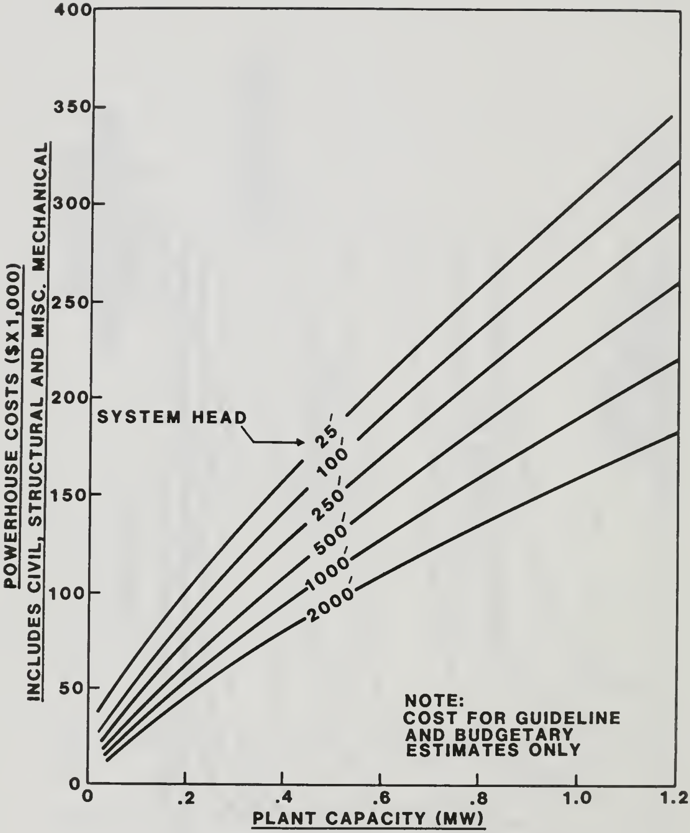


FIGURE I-9
POWERHOUSE COST

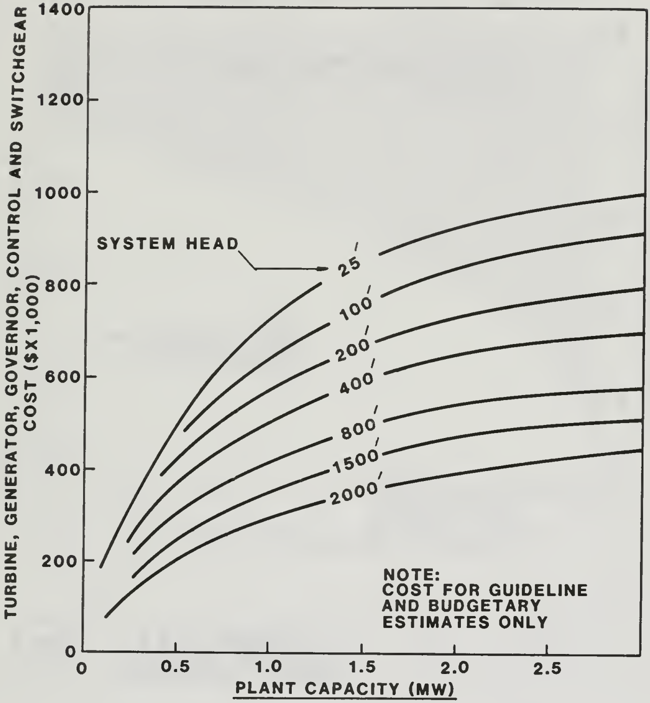


FIGURE I-10
TURBINE & MACHINERY COST

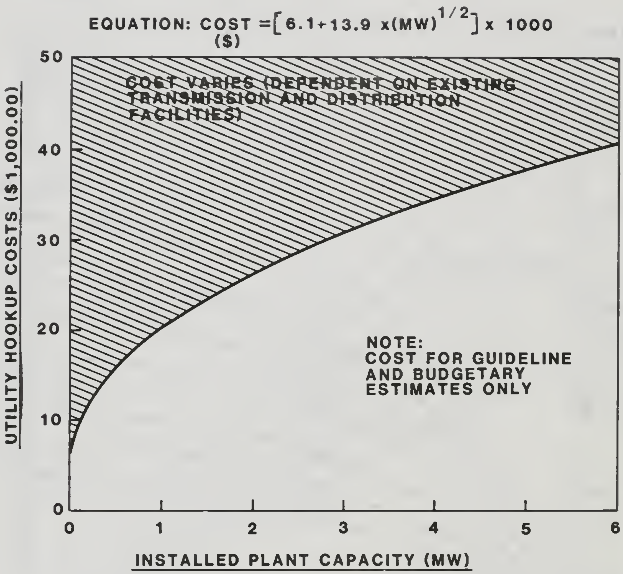


FIGURE I-11
UTILITY HOOKUP

OTT

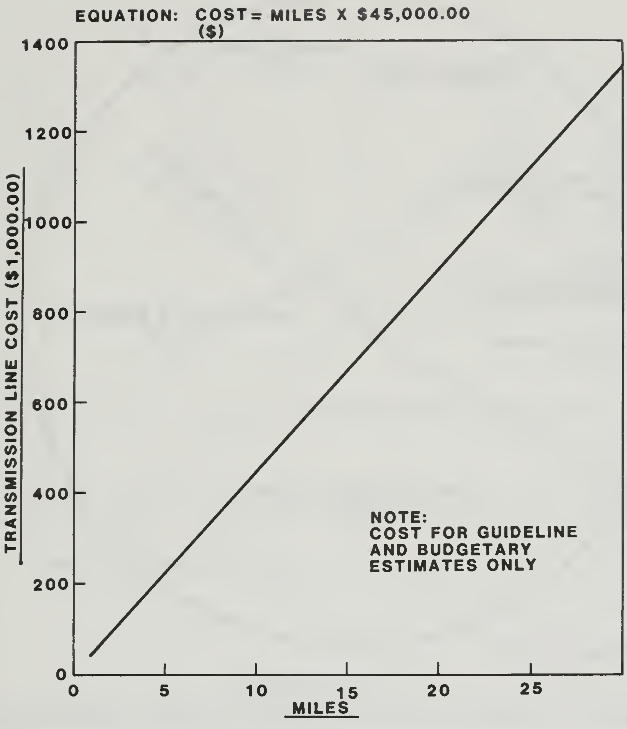


FIGURE I-12
TRANSMISSION LINE
(INSTALLED COST)

OTT

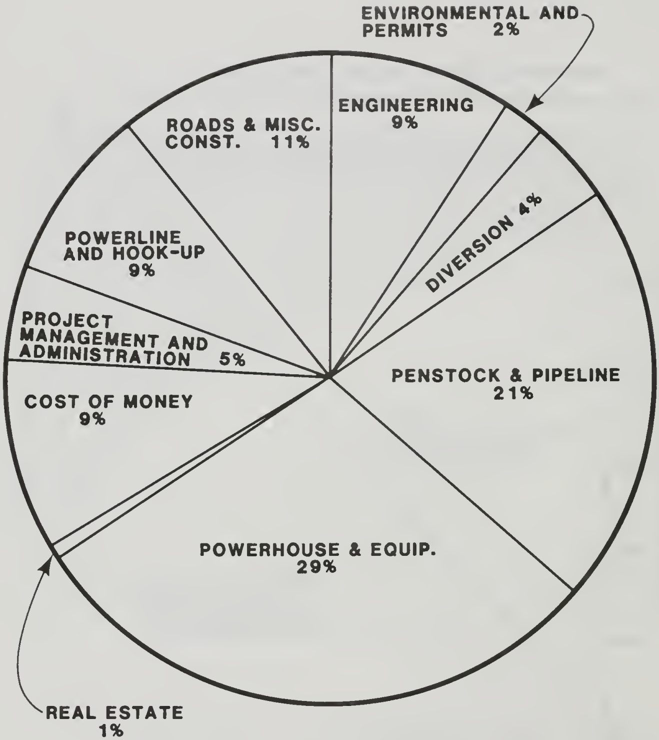


FIGURE I-13
COST BREAKDOWN FOR A RECENT RUN-OF-RIVER PROJECT

OTT

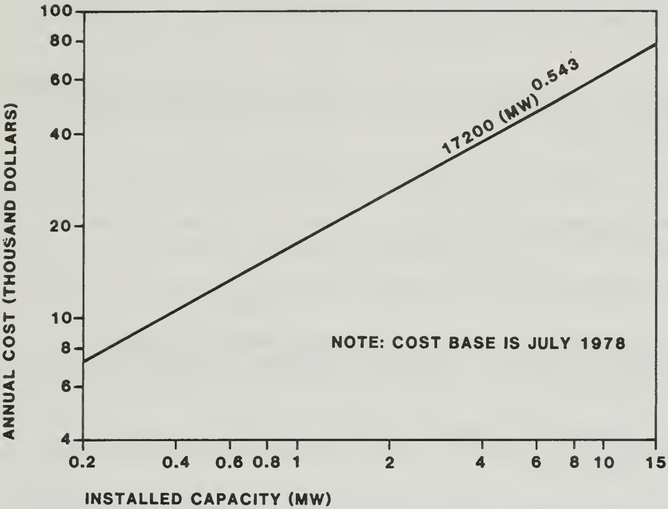


FIGURE I-14
OPERATION, MAINTENANCE AND REPLACEMENT COSTS

TUDOR

SUPPLEMENTARY REFERENCES _ CHAPTER I

The following reports may prove valuable in assessing project feasibility:

I-1. Building and Operating a Small Scale Hydroelectric Power Plant, Proceedings from a short course sponsored by University of California at Berkeley, January 1982.

I-2. Feasibility Studies for Small Hydropower Additions - A Guide Manual, U. S. Army Corps of Engineers, Hydrologic Engineering Center, 609 2nd Street, Davis, CA 95616, Cost $14.00.

I-3. Reconnaissance Evaluation of Small Low-Head Hydroelectric Installations, prepared by Tudor Engineering for: Water and Power Resources Service, Engineering Center, Denver Federal Center, Denver, Colorado 80226 (303) 234-3166.

Additional documents which address various aspects of hydropower site development include:

I-4. A Guide to Micro-Hydro Development in Washington, Washington State Energy Office, 400 East Union Street, Olympia, WA 98504.

I-5. Small Hydro, by John Stuart Gladwell, Idaho Water Resources Research Institute, University of Idaho, Moscow, ID 83543.

I-6. Small Hydroelectric Potential at Existing Hydraulic Structures in California, Bulletin #211, California Department of Natural Resources, Box 388, Sacramento, CA 95800, Cost $15.00, Appendices separately bound $10.00.

I-7. Small Hydroelectric Systems: A Guide to Development in California, California Energy Commission, 1111 Howe Avenue, Sacramento, California 95825, Sept. 1981.

I-8. Water Over the Dam - A Small Scale Hydro Workbook for Colorado, Colorado Office of Energy Conservation, 1525 Sherman Street, Denver, CO 80203.

Chapter II

PERMITTING AND LICENSING REQUIREMENTS

INTRODUCTION

This chapter is intended to serve as a guide for individuals in satisfying the local, state, and federal requirements for construction of a hydropower generation facility in Montana. These requirements are concerned with a wide variety of issues such as legal rights, public safety and environmental concerns and many apply to other types of projects in addition to hydropower development.

Time Requirements

Although numerous agencies have potential permitting or review authority, small hydro projects are likely to require only a few permits. Nevertheless, the time requirement for obtaining all permits and licenses may be a substantial part of the total project duration. It is therefore important for the site developer to initiate the permitting process in the early stages of the project development. Specific time requirements may be found in the sections describing the individual permits.

Permitting Process Helpful

In spite of appearing as a series of barriers to developers, the permitting process may actually be beneficial. By corresponding with appropriate agency officials during the preliminary design and analysis phase, potential problems with a particular site or design can be spotted early. Appropriate modification can then be made thus avoiding last minute delay.

Hydropower Information

Satisfying licensing and permitting requirements is only one of several important phases of developing hydropower projects. Accordingly a "Hydropower Information Center" has been established to aid developers seeking information not contained in this document. Inquiries should be directed to:

Hydropower Information Center
Montana University Joint Water Resources Research Center
Montana State University
Bozeman, MT 59717
(406) 994-2891

LOCAL PERMITTING PROCESS

Early in the development process a developer should contact local, city, and county planning and public works departments. These departments should be able to inform the developer of all local permits the project will require. All local permit requirements must be satisfied prior to or concurrently with applications for use and occupancy of federal land and application to the Federal Energy Regulatory Commission (FERC) for exemption or license.

The county planning department can inform the developer of any zoning and land use restrictions. Conditional use permits may be required by the county planning department for projects requiring the use of or the crossing of land under county jurisdiction. Generating facilities impacting only the developer's property should encounter few problems. More substantial generating facilities may be referred to hearings before the planning commission or county commissioners to determine if the project is in the public interest.

For those areas under county jurisdiction, building and electrical permits from the public works or building department are generally required. The project plans will be reviewed for compliance with Montana building and electrical code requirements. Operations on county roads may also require permits from the public works department.

STATE PERMITTING PROCESS

In Montana, it is very likely that a hydropower developer will at least have to obtain the following permits from the Department of Natural Resources and Conservation (DNRC), 32 South Ewing, Helena, MT 59620:

1) a water right permit (Water Resources Division of DNRC)
2) a "310 permit" (administered by the Conservation Districts, DNRC).

Other state agencies which may require permits or otherwise act in a review capacity include: Montana Department of Health and Environmental Sciences, Department of State Lands, Department of Fish, Wildlife and Parks, and the Engineering Bureau of the DNRC. Requirements of each agency are summarized below.

"Water Right Permit"- Water Resources Division, DNRC

A water right permit to use water for a hydro project is necessary in all cases where surface water (meaning streams, rivers, lakes, natural ponds, undeveloped springs, etc.) will be used or if a groundwater source (meaning wells, pits, developed springs, etc.) with a maximum appropriation of 100 gallons per minute of water or more will be used. However, if the hydropower project is located outside the boundary of a controlled groundwater area, a permit is not required before appropriating groundwater by means of a well or developed spring with a maximum appropriation of less than 100 gallons per minute (Notice of Completion of Groundwater Development Form No. 602-must be filed, however, to obtain a water right).

If the small hydro developer has an existing water right, the law also provides for changes of that right as it relates to changing the place of diversion, place of use, purpose of use, or place of storage.

Application for Beneficial Water Use Permits (Form No. 600), Notices of Completion of Ground Water Development (Form No. 602), and Applications for change of Appropriation Water Right (Form No. 606) may be obtained from the Water Resources Division, Dept. of Natural Resources and Conservation, 32 South Ewing, Helena, MT 59620, at the local county clerk and recorders offices or from any of the Water Rights Bureau offices located in Bozeman, Helena, Missoula, Kalispell, Havre, Glasgow, Lewistown, Miles City, or Billings. It is recommended that at least six months be allowed to process the permit or change of application request.

"310 Permit" - Conservation Districts, DNRC

In applying for a 310 permit, the applicant must comply with the provisions set forth in the Natural Stream Bed and Land Preservation Act, which came into existence during the 1975 Legislative Session with the passage of Senate Bill 310. The purpose of this act is to protect and preserve the natural rivers and streams and the land and property immediately adjacent to them, to prohibit unauthorized projects and protect the use of water for any useful or beneficial purpose as guaranteed by the constitution of the State of Montana. The Act applies to all private individuals and corporations on private land. It does not apply to federal or state projects on federal or state land or Indian projects on Indian Reservations.

Potential hydropower developers shall present written notice of the project to their local conservation district supervisors. Pertinent forms may be obtained at the local conservation district office. There is at least one conservation district in each county with most district offices being located with the USDA Soil Conservation Service Office in the county seats. At least 60 days should be allowed in order to secure a 310 permit.

"Easement"-Department of State Lands

The Department of State Lands will be involved in the permitting process for hydropower development if the proposed project is on state school trust land or on a navigable stream (the beds of navigable streams are owned by the state). Either of these situations would require that the applicant obtain an easement from the Department of State Lands. Two types of easements are available; "Permanent Easements" require the approval of the Board of Land Commissioners, with applications requiring about two or three months for approval. "Temporary construction permits" along or adjacent to permanent easements may be granted by license agreement with the Department. Another important factor is that the Department is required to obtain full market value for all easements on state lands, thus that price would have to be determined and sought.

Inquiries should be directed to either the Administrator, Land Administration Division or Chief, Land Management Bureau, Department of State Lands, Capital Station, Helena, MT 59620.

"Short Term Authorization" - Department of Health and Environmental Sciences (DHES)

The DHES should be contacted during the initial stages of project development to determine if a "short term authorization" (allowing for the temporary discharge of pollutants during project construction) will be required. Inquiries should be directed to the following address:

Mr. Fred Shewman, Head
Permitting Section
Water Quality Bureau
Dept. of Health & Environmental Sciences
Cogswell Building
Helena, MT 59620

The DHES may also participate when proposed projects are reviewed under the Natural Streambed and Land Preservation Act for issuance of the 310 Permit.

"Review Authority" - Department of Fish, Wildlife and Parks

Although the Department of Fish, Wildlife and Parks (DFWP) does not have permitting authority per se, they are entrusted with extensive review authority and thus play a major role in determining the eligibility of the applicant to receive other necessary permits including the FERC license. The DFWP is concerned with environmental impacts of proposed projects including adverse effects on fish, wildlife and recreation in the evaluation of any particular site. The DFWP would be concerned with the following specific items:

1) flow fluctuations on a daily basis or operation of existing flow regime on a seasonal basis
2) alterations in water temperature or other water quality parameters resulting from location or means of water withdrawal/discharge
3) impacts associated with possible increased reservoir operating level or increase in extent of winter drawdown
4) impacts associated with power line siting, construction and operation
5) impacts to the riparian habitat, streambank and/or streambed associated with power plant construction and operation
6) potential for streambank erosion downstream
7) frequency and extent of future repair or maintenance.

It is strongly recommended that contact be made with the Department of Fish, Wildlife and Parks early in the preliminary design phase of project development in order to eliminate possible problems early in the process.

Address correspondence to:

Director's Office
Department of Fish, Wildlife and Parks
1420 East Sixth Avenue
Helena, MT 59620

"Flood Plain Development Permit" - Engineering Bureau, DNRC

If a hydropower project site is located within the boundaries of a designated floodplain, the applicant should contact the local floodplain administrator (county commissioners, city planning department, or other designated official) and, if necessary, obtain a floodplain development permit application. In most cases a permit would be necessary to place a small hydro project in a floodplain. Usually the permit application is acted upon within 60 days after receipt unless additional information is necessary or an environmental impact statement is required. For more information contact:

Floodplain Management Section - Engineering Bureau
Department of Natural Resources and Conservation
32 South Ewing
Helena, MT 59620
(406) 449-2864

FEDERAL PERMITS AND LICENSING

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC), formerly the Federal Power Commission, is the federal agency responsible for issuing licenses for non-federal hydroelectric projects under its jurisdiction. Montana west of the Continental Divide is administered by the San Francisco Office of FERC (333 Market Street, San Francisco, CA 94105) while the Chicago Office (31st Floor, Federal Bldg., 230 S. Dearborn St., Chicago, IL 60604) administers the remainder of the state.

A hydropower project is within the jurisdiction of FERC and, must obtain a license or an exemption from licensing if any of the following apply:

1) the project will be on a navigable waterway
2) power from the project will enter into utility systems which affect interstate commerce;
3) the project will utilize federal land
4) the project will use surplus water or waterpower from a federal dam.

Projects which do not affect a navigable waterway or interstate commerce or federal lands or dams would not be subject to FERC jurisdiction.

If there is uncertainty regarding FERC jurisdiction, the hydro developer should contact the FERC for an opinion(Federal Energy Regulatory Commission, 825 N. Capitol Street, N.E., Washington, D. C. 20426, attention: Director of Hydropower licensing). The FERC "Blue Book", entitled Procedures to Apply for Hydropower Licenses and Preliminary Permits can also be obtained from this address. Information contained in the Blue Book is essential to the Federal Permitting and Licensing process.

FERC-Preliminary Permit

A preliminary permit protects a developer's priority to apply for a license for a particular site for a period of up to three years while an application for license or exemption is being prepared. Although not a prerequisite for licensing, the preliminary permit is highly recommended as it provides priority to the site to the permittee if a license or exemption application is filed within the permit term. The permit does not authorize construction.

An application consists of an initial statement and four exhibits. The initial statement provides the identity of the applicant, the name and location of the proposed project, and the proposed term of the permit. Exhibit 1 is a description of the proposed project. Exhibit 2 consists of a plan and schedule for the activities to be carried out under the permit. This includes dates for a final feasibility decision and for a license application date. Exhibit 3 is a statement of cost, financing, and marketing for the studies to be completed under the preliminary permit. Exhibit 4 is a map showing the location of the project, the physical relationships of its principal features, and proposed boundaries.

The original application and 14 copies are sent to the Washington, D. C., Office of FERC.

FERC Licenses

FERC issues licenses to construct and operate hydroelectric projects for a term of up to 50 years. A new license may be applied for when a previous license expires.

There are three categories of FERC licenses:

1) MINOR PROJECTS (SHORT FORM LICENSE) - 5 MW OR LESS CAPACITY
2) MAJOR PROJECTS AT EXISTING DAMS - GREATER THAN 5 MW CAPACITY
3) UNCONSTRUCTED MAJOR PROJECTS - GREATER THAN 5 MW CAPACITY

Minor Projects: The "Short form" license application (for projects under 5 MW installed capacity) requires information on the size, location, use, and ownership of the project, evidence of compliance with state water laws and other state laws, and a construction schedule. Four exhibits are required. Exhibit A contains the project description and mode of operation. Exhibit E provides a report on the environmental resources of the project and the impact of the project on those resources.

Exhibit F consists of general design drawings of the principal project works. Exhibit G is a map of the project (Order No. 185, 18 CFR).

Major Projects at Existing Dams: This category of applications applies to projects with over 5 MW installed capacity which seek: (1) an initial license for an existing hydroelectric project, (2) a renewed license for an existing project, or (3) an initial license for a proposed hydroelectric project at an existing dam. The application requires an initial statement and seven exhibits. The initial statement provides certain basic information necessary for identification and orientation purposes, including the nature of the application, the name, business address, and telephone number of the applicant and its authorized agents, the status of the applicant, and the name and location of the project. The applicant is also required to demonstrate compliance with the laws of the state where the project is located with respect to obtaining property rights and the rights to appropriate, divert, and use water for power purposes. Applicant must also obtain authorization to engage in the business of producing, transmitting, and distributing power, and any other business necessary to accomplish the purposes of the requested license.

Exhibit A provides a description of the physical structures and features of the project. The exhibit also includes a tabulation of any lands of the United States that are enclosed within the project boundary.

Exhibit B provides a statement of project operation and resource utilization.

Exhibit C provides a construction history and a proposed construction schedule for the project.

Exhibit D provides a statement of costs and financing.

Exhibit E provides a report on the environmental resources of the project, the impacts of the project on those resources, and the proposed measures to mitigate the impacts or to protect and enhance the resources.

Exhibit F consists of general design drawings of the principal project works.

The final exhibit, Exhibit G, is a map of the project.

For exact specifications for this license application, refer to FERC "Blue Book" or the Commission's Regulations (18 CFR).

Unconstructed Major Projects: A license application for an unconstructed project over 5 MW installed capacity consists of the same initial statement and seven exhibits as for "Major Projects at Existing Dams". In addition, a project which satisfies certain requirements may qualify for an exemption from the licensing process. There are presently two categories of case-by-case exemptions:

1) projects less than 15 MW that utilize conduits originally built for purposes other than hydropower generation

2) certain projects not exceeding 5 MW on natural water features as described in Docket No. RM 80-65; order no. 106 and 106-A and 18CFR.

Applicant should contact the Washington Office of FERC for details regarding exemptions.

Conduit Facilities: Section 30 of the Federal Power Act authorizes FERC to exempt small conduit hydro facilities from all or part of the normal licensing requirements. To qualify, a project must be on a conduit, canal, pipeline, etc., built for other primary purposes, such as domestic, agricultural, or industrial purposes. It must not utilize a new dam for the increased head necessary for power generation; the powerhouse cannot be on federal land; and the project capacity cannot exceed 15 MW. Under FERC regulations, applications will be considered on a case-by-case basis, and must be acted upon within 90 days of notifying the applicant that an acceptable application has been received, otherwise, the exemption will become effective automatically.

The application consists of an introductory statement and four exhibits. The introductory statement identifies the applicant and locates the project. Exhibits include: (1) a description of the conduit, the purposes for which it is currently used, and the proposed mode of operation, (2) a general location map showing land ownership and the location of the physical structures of the facility, (3) an environmental report that must include, in some detail, the siting of the facility, expected impacts and proposed measures to mitigate them, (4) a description of alternative means of obtaining the equivalent amount of power produced, (5) evidence that the applicant consulted with state and federal fish and wildlife agencies and any determinations of these agencies, and (6) a set of drawings of the facility structures and equipment. This must include a plan, elevation, and profile view of the power plant and any dam to which the plant would be attached. Detailed specifications can be found in order No. 76 (Federal Register of April 28, 1980 (45 FR 28085)), 18 CFR 4.90 18 CFR, 4.94, or obtained from FERC.

OTHER FEDERAL PERMITS

U.S. Army Corps of Engineers "404" and "Section 10" Permits

The Corps of Engineers has jurisdiction over any project which is proposed for a navigable waterway (Section 10, River & Harbor Act of 1899), or which involves the discharge of any dredge or fill material into waters of the U.S. (Section 404, Federal Water Pollution Control Act).

In general, the Corps does not require a separate Section 10 permit in cases where FERC exercises licensing jurisdiction. However, the Corps does review and comment on FERC applications as a part of the FERC's pre-license consultation process to ensure the protection of navigational interests. For projects involving the discharge of dredged or fill material into waters of the U.S., a 404 permit is required in addition to any FERC license.

These permit applications are made on a general form and take approximately three to six months for approval. It requires information on the nature and location of the proposed activity, the time span involved, and the status of other federal, state, and local permits. The Corps, upon receipt of the application, issues public notice and requests comment. The FERC license application should be on file. After 30 days, the agencies will respond with approval, request a hearing, or request a hold. Comments are also requested from local, county, and state agencies. After approvals from agencies are granted, and the final National Environmental Protection Agency Environmental Impact Statement (NEPA EIS) is approved, the permit may be issued.

The North Pacific Division administers the Corps of Engineers program for the area west of the Continental Divide. Montana east of the divide is administered by the Missouri River Basin Division. Addresses are as follows:

Division Engineer
North Pacific Division
P. O. Box 2870
Portland, OR 97205
Telephone: (503) 221-3751

Division Engineer
Missouri River Division
Box 103 Downtown Sta.
Omaha, NB 68101
Telephone: (402) 221-7347

"Determination of No Hazard" Federal Aviation Administration (FAA)

Approval of this permit requires approximately two months. The FAA has the forms which must be completed, and they will be reviewed to see if any project feature (e.g., transmission towers) constitutes a hazard to aviation. A project layout showing elevation contours should be turned in with the application, and information on microwave towers and existing airports in the project area may be required.

"Memorandum of Understanding" - U.S. Forest Service (USFS)

If any part of the project is located on National Forest System lands, authorization from the Forest Service is required.

On projects for which the applicant seeks a preliminary permit or license under the Federal Power Act, FERC and the Forest Service require that a Memorandum of Understanding or special use authorization be executed between the applicant and Forest Service before studies start on National Forest System lands. Approval of a Memorandum of Understanding or special use authorization will take approximately 3 months, depending on the project. This will provide for project studies and investigation only; no construction is authorized at this point. The Forest Service prefers to authorize such studies under a special use permit. Applicant should consult with the District Ranger early in the design phase of the project to gain an understanding of information and data required for a Forest Service decision on project authorization. The following kinds of information should be provided:

> A general project plan and schedule, a description of the roads and facilities which are to be inundated or impacted, a description of proposed construction, scheduling, design, location, and drainage provisions, the proposed clearing plan and clearing method for the reservoir, location of slash disposal, borrow, and waste area, powerline locations, impact mitigation, and methods of fire prevention. The Forest Service will inform the applicant of any additional information needed, and the scope and depth of that information.

If FERC grants an exemption from the Federal Power Act under it's authority and the project is located on National Forest System lands, the project is authorized by the Forest Service through a special use permit. A preliminary or study permit may be issued to perform on-site investigation to obtain data necessary for final decision process. The study permit will require general project scope and site data to be developed, including hydrologic, wildlife, and fisheries information. Detailed plans and specifications, operational plans and schedules, etc., will be necessary as a part of the application for a special use permit authorizing project construction and operations.

Federal Communications Commission (FCC)

Hydroelectric projects utilizing remote radio operation will require a FCC permit.

Bureau of Land Management (BLM)

If a project involves a permanent use of Bureau of Land Management lands the developer must obtain a "Right-of-Way Authorization" from the local district BLM office. Applicants must negotiate an annual rental agreement which will be based on current land values. "Temporary Use Permits" are also available along with "Construction Materials Sales" permits.

Historic Preservation Legislation

In Montana, hydropower developers must comply with federal and state requirements for protection of cultural resources. It is recommended that the Montana Historical Society should be contacted as a first step in this compliance procedure. The Historical Society, in addition to providing details regarding compliance, may have historic and/or archaeological information on file which could be useful in assessing a particular hydropower site. Please direct inquiries to:

Montana Historical Society
Historic Preservation Office
225 North Roberts Street
Helena, MT 59601
(406) 449-4584

The primary federal historic preservation mandates are Executive Order 11493, the National Historic Preservation Act of 1966 (NHPA), as amended, and 36 CFR800, the regulations implementing the NHPA. These require that federal undertakings or undertakings involving federal assistance, licenses or permits take into consideration the impact upon cultural resources. The steps of compliance can be broken down into three general areas of concern:

1) Identification of cultural resources located with the project's area of environmental impact. Initial consultation on the part of the federal agency or permittee with the Montana Historic Preservation Office should include a concise description of the type of undertaking planned with the location and areal extent of land disturbance (including right-of-way clearing, powerhouse and transmission line construction) either shown on accompanying maps or clearly defined under the project description. In response, the Preservation Office will furnish the results of a cultural resource site file search, including information on archaeological or historic sites survey work that may have occurred in or near the project area and recommendations for any further work that may be necessary to identify sites thought likely to be present which could be affected by any project activities that are planned.

2) Evaluation of properties located as a result of a cultural resource survey. After any properties that have been identified in the project area have been fully recorded by qualified personnel, their significance is assessed in terms of integrity, historic association, artistic merit, or ability to yield important information on prehistoric lifeways.

3) Mitigation of Impact. The federal agency through its permittees or applicants must ensure that measures to avoid or minimize the adverse effects which threaten a cultural property and the qualities and features that lend significance to it are carefully considered during the course of project planning.

The state Antiquities Act, revised in 1979, pertains to "state actions or state assisted or licensed action" and requires that heritage properties (i.e., significant historic, archaeological, and architectural properties) and paleontological remains situated on state lands be identified and protected. As yet, there are no regulations governing state agencies and their permit applicants in carrying out antiquities-related matters. Procedurally, most actions involving land disturbances on state land would be reviewed along the same lines as federally aided undertakings.

Chapter III

PROJECT FINANCE

FINANCIAL INCENTIVES

A desire to stimulate the development of renewable resources for energy production has led federal and state governments to authorize a variety of programs which offer incentives to hydropower developers. The following information which summarizes these programs has been taken mainly from Oregon Hydropower Development, September 1981.

Loans

In recent years, prospects for hydropower developers receiving financial assistance from the Federal Government have been diminished due to extensive cuts in the federal budget and the resultant elimination of certain agencies and programs. Developers should contact the state and federal agencies described in Figure III-1 for possible financial assistance.

Tax Incentives

The following summary provides an overview of those aspects of Federal Income Tax laws which have particular application to small hydro development. Internal Revenue Service (IRS) officials have cautioned that the status and content of the following tax laws could change substantially with the signing of the Reagan administration's tax package. Hydro developers are advised to consult with the IRS or a tax consultant as to any further changes of the following laws.

Deductions From Gross Income. The most pertinent provisions of the Internal Revenue Code affecting the finances of a hydro project in the early stages of development are those which allow for: (1) current deductions from gross income for ordinary and necessary business expenses, (2) depreciation of certain capital expenditures, and (3) net operating loss carryovers.

1. Ordinary and Necessary Business Expenses

   The Internal Revenue Code (IRC) allows as a deduction from gross income those expenses incurred as the result of running a business. Developers should consult section 162 of the IRC for a complete account of deductions.

2. Depreciation of Certain Capital Expenditures

   The Internal Revenue Code Section 167 provides an incentive to invest in certain types of property. As a general rule, the

Figure III-1. Small Hydro Loan/Grant Programs

Agency	Contact	Eligibility
Rural Electrification Administration	Ken Anderson, REA Washington, DC 20250 (202) 447-5723	Nonprofit organizations Municipalities < 1500 people Rural Electric Coops
Farmers Home Administration "Small Business Loan Program"	Clayton Schievelbein, District Manager Box 398 Bozeman, MT 59715 (406) 587-5271	Municipalities, Counties, districts, authorities or other political subdivisions of a state
Small Business Administration "Small Business Loan Program"	Dave Davidson USSBA 301 S. Park Federal Bldg., Rm 528, Drawer 10054 Helena, MT 59601 (406) 449-5381	Any small business as defined by SBA
U.S. Dept. of Housing and Urban Development "Energy Loan Program"	Ken Crandal Dept. of H.U.D. Single Family Architects and Engineers Div. 1405 Curtis St. Denver, CO 80202 (303) 837-2475	Any city or urban community meeting certain requirements set by HUD
Bonneville Power Administration "Pacific NW Electric Power Planning & Conservation Act"	Director, Div. of Resource Development & Acquisition 1002 N.E. Hollanday St. Box 3621 Portland, OR 97206 (503) 230-5341	All developers subject to certain limitations set by BPA
Montana Dept. of Natural Resources and Conservation Energy Division	Jeanne Thurston 32 S. Ewing Helena, MT 59620 (406) 449-3940	All developers
Montana Dept. of Natural Resources and Conservation Water Development Bureau	Carol Chaney, Water Resources Division Water Development Bureau 28 S. Rodney Helena, MT 59620 (406) 449-3760	All developers

amount invested may be deducted from gross income over the useful life of the property acquired. The following expenditures have been accorded this treatment: legal and engineering fees associated with property acquisition, land preparation in relation to construction of a dam, and flood plain easement acquisition.

It should be noted that legal fees associated with the initial acquisition of a license renewable for an indefinite period constitute a nonamortizable capital expenditure deductible only when the license is revoked or abandoned.

3. Net Operating Loss Carryover - IRC Section 172

Non-municipal corporations involved in small hydro development may be entitled to utilize the net operating loss carryover provision of the IRC. This entitles a corporation to apply any deductions (with certain adjustments) in excess of gross income against its gross income in subsequent tax years. A net operating loss may be carried forward for five years. Thus, a developer whose income flow develops years after deductible expenses are incurred does not lose the value of the deductions.

Investment Tax Credits. Title II, Part II, of the Crude Oil Windfall Profits Tax Act of 1980 allows an 11 percent business energy credit for investment in qualifying hydroelectric projects. This credit is in addition to the long-standing 10 percent investment tax credit. The new 11 percent credit is available at both existing and developable sites. It is available at existing dams which were completed before October 18, 1979, and at new or existing natural or manmade water flows (rivers, conduits, irrigation ditches, etc.) not at a dam site. This credit is available to all licensed businesses, and applies to generating equipment such as turbines, generators, powerhouses, penstocks, and fish passageways. It also applies to reconstruction or rehabilitation of dams. The energy credit is not valid in the total plant capacity range of 25 to 125 MW.

LEGISLATION

Public Utility Regulatory Policies Act (PURPA)

As part of the National Energy Act of 1978, PURPA was signed into law on November 9, 1978. Title II of PURPA establishes certain utility requirements beneficial to small hydroelectric development which are discussed below.

Electric utilities are now required to purchase any excess power offered for sale by "qualifying facilities" (QF). A QF is one that is no more than 50 percent owned by a public utility and has a power production capacity of 50 MW or less.

The rate which electric utilities are required to pay a QF has three restrictions. Rates for purchases shall be just and reasonable, not discriminatory against the QF, and shall not exceed the utilities' "avoided costs". Avoided costs are defined as the incremental costs to an electric utility of electric energy or capacity or both which, but for the purchase from the QF, such utility would generate itself or purchase from another source.

PURPA authorizes FERC to exempt qualifying facilities (up to 30 MW) from certain provisions of the Federal Power Act and the Public Utility Holding Company Act, as well as the financial and organizational regulations of electric utilities.

PURPA requires FERC to issue regulations defining QF's and setting standards for rates.

In Montana, the Public Service Commission (PSC), which is regulated by FERC, has the authority to set rates which private utilities are required to pay for power produced by a hydroelectric facility. Details concerning energy price schedules and power sales agreements are given in Chapter IV.

Pacific Northwest Electric Power Planning and Conservation Act

The Northwest Regional Power Bill was signed into law on December 6, 1980 to become Public Law 96-501. Entitled the "Pacific Northwest Electric Power Planning and Conservation Act", the Act includes financial incentives to encourage development of renewable energy resources including hydroelectric power. The Act authorizes the Bonneville Power Administration (BPA) to:

1) enter into long term contracts to purchase the output from hydro projects
2) provide billing credits to utilities and others that develop hydropower
3) pay for feasibility studies and preliminary engineering for renewable resource projects (note that this is not limited to existing dams)

BPA is authorized to reimburse the sponsor of a resource project for certain investigation and pre-construction costs, but with significant limitations. For details of this and other programs listed here, contact the following BPA office:

Director
Division of Resource Development & Acquisition
1002 N.E. Holladay Street
P. O. Box 3621
Portland, OR 97208
(503) 230-5341

or

BPA's Public Co-ordinator's Office can be reached toll free in Montana

1-800-547-6048.

CHAPTER IV

POWER SALES AGREEMENTS

Hydropower developers in Montana will sell power to one of four major utilities; Montana Power Company (MPC), Montana Dakota Utility (MDU), Bonneville Power Administration (BPA), or Pacific Power and Light (PPL), or to a rural electric cooperative. Basic requirements for interfacing small hydro systems with a utility transmission grid have been laid down by the Montana Public Service Commission (March 1982) in conformance with the Public Utilities Regulatory Policies Act (PURPA), passed by Congress in 1978. Subsequently MPC, MDU, and PPL have developed their own set of guidelines and requirements for small hydro developers wishing to enter into a power sales agreement. Bonneville Power Administration is still in the process of developing resource acquisition policies and therefore substantive comments regarding BPA do not appear in this chapter. Inquiries regarding power sale negotiations should be directed to the following addresses:

Mr. Peter Antonioli, Director
Conservation/Renewable Resources Div.
Montana Power Co.
40 E. Broadway
Butte, MT 59701
(406) 723-5421

Mr. Carl Ertler, Manager
Renewable Energy Department
Pacific Power and Light Co.
920 W. Sixth Ave.
Portland, OR 97204
(503) 243-1122

E. E. Anfinson, Asst. Div. Manager
Montana Dakota Utilities Co.
Box 201
Glendive, MT 59330
(406) 365-5251

G. H. Brandenburger
Kalispell District Manager
Bonneville Power Administration
Box 758
Kalispell, MT 59901
(406) 755-6202

AGREEMENT TERMS

Many of the terms of a power sales agreement must be negotiated between the developer and the utility and therefore the nature of these agreements will be discussed here only in general terms. The intention of this discussion is to acquaint the developer with the interfacing requirements as well as to give an overview of energy price information.

Liability and Insurance

The cogeneration or small power producing (COG/SPP) facility may be required to carry sufficient insurance to cover any damage or injury to persons, animals, property, environment, etc., caused by the operation of the facility.

Government Jurisdiction and Authorization

The contract agreement may not become effective until all necessary governmental permits and authorizations have been obtained and submitted to the utility company. Additionally, the agreement may at all times be subject to changes by regulatory agencies. If after the agreement becomes effective, any regulatory agency, having control over either party, requires changes or imposes conditions or obligations on either party which either party decides are unreasonable, such party may terminate the agreement.

Operating Reserve Capacity

Payment for the avoided capacity may be increased if the utility company does not provide operating reserve capacity. The seller's facility must prove capable of supplying contract capacity to the utility for a fixed percentage of the time that the seller has committed to supply capacity during each contract year.

Interconnection Equipment

The COG/SPP facility may be required to construct, install, own, and maintain interconnection equipment to interface and deliver energy and capacity to the utility's system. The utility will review and test all such interconnection equipment. In the event that it is necessary for the utility to construct, install, or maintain interconnection equipment, the COG/SPP facility may be required to reimburse the utility for all costs associated with the interconnection.

Metering

Appropriate metering equipment shall be furnished and installed on the facility by the utility at the expense of the COG/SPP seller.

Interconnection Equipment Required

The COG/SPP seller's property listed below will be operated and maintained in good working order by Seller:

1. A lockable main disconnect switch which allows isolation of seller's facility from the utility's system. This disconnect switch will be located by mutual agreement of the utility and the COG/SPP seller, and will be accessable and operable at all times by qualified employees or agents of the utility as well as the seller.
2. An automatic disconnecting device which is designed to operate in conjunction with and in response to appropriate relays and protective devices.

3. Relays and controls required by company.

4. Equipment as required to establish and maintain facility generation operation in synchronism with company's system.

The seller shall operate and maintain his facility and equipment according to prudent electrical practices. The instantaneous reactive power consumed or furnished by the facility shall not exceed a fixed percentage of the real power being generated by the facility.

<u>Distortions</u>

The COG/SPP seller shall remedy any harmonic distortion caused by the facility resulting in objectionable service to the utility's other customers. If the seller does not take corrective action, the utility's may, without incurring liability, disconnect the seller's facility from the utility's system.

<u>Non-Performance</u>

If, for any reason other than force majeure, the COG/SPP seller is unable to supply contract capacity during any contract year, payments for capacity may be suspended until such time as the utility and the COG/SPP seller can mutually agree to a reduced contract capacity amount for the COG/SPP seller's facility.

PRICE FOR ENERGY

Hydropower developers may contract with the Montana public utilities on either a "short term" (1-4 year) or a "long term (5-35 year) basis. Rate schedule information as of August 1982 is as follows:

Utility	Short Term Rate	Long Term Rate
Montana Power Co.	2.34¢/KWH	5.33¢/KWH
Montana-Dakota Utilities Co.	2.16¢/KWH	5.23¢/KWH
Pacific Power & Light Co.	2.28¢/KWH	4.99¢/KWH
Bonneville Power Co.	No established rate schedule	

Copies of power purchase agreements for MPC, PPL and MDU (as of June 1982) appear on the following pages. Rural Electric cooperatives should be contacted directly to obtain similar information.

Form 4G-B

Public Service Commission of Montana

The Montana Power Company — Sheet No. STPP-82

(Name of Company) — Cancelling Sheet No. None

Schedule STPP-82

Short-Term Power Purchase Service

AVAILABILITY: To any Seller who operates facilities for the purpose of generating short-term electric energy in parallel with the Company's system. This schedule is applicable to Cogeneration and Small Power Production (COG/SPP) facilities that are Qualifying Facilities under the Rules of the MPSC.

DEFINITIONS: "Seller," for purposes of this schedule, is any individual, partnership, corporation, association, government agency, political subdivision, municipality, or other entity that:

1. Operates a qualifying COG/SPP facility;

2. Has signed the standard written contract with the Company stipulating the terms and conditions of the interconnection and sale of electricity to the Company;

3. Has agreed in the standard contract to provide electricity to the Company on a short-term basis as defined in the contract.

"Company" means The Montana Power Company.

"MPSC" means The Montana Public Service Commission.

"Contract Year" means twelve months beginning on July 1.

RATE: $0.0234/kWh

SPECIAL TERMS AND CONDITIONS:

1. Change of Rate: This schedule will be reviewed annually for each Contract Year and revised upon MPSC approval.

2. Net Billing Option: If the Seller opts for Short-Term Net Billing in the standard contract and the Seller's consumption kWh exceeds the production kWh, the Seller will be billed only for the consumption kWh in excess of production kWh according to the Company's applicable Retail Sales Rate Schedule. If the Seller's consumption kWh is less than the production kWh, the Seller will receive payment for only the production kWh in

Issued .... (Date) By .... (Signature of Officer of Utility)

Approved .... (Date) Effective .... (Date)

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PUBLIC SERVICE COMMISSION OF MONTANA.

.... Secretary

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Form 63-B

Public Service Commission of Montana

The Montana Power Company
(Name of Company)

Sheet No. STPP-82
Cancelling Sheet No. None
Page 2 of 2

Schedule STPP-82

Short-Term Power Purchase Service

excess of consumption kWh according to the energy rate in this schedule. A Seller under this Option will receive no separate payment for capacity, and all metered consumption kW (if applicable) will be billed to the Seller according to the Company's applicable Retail Sales Rate Schedule. If the Seller is demand-metered for consumption, the Seller will be required to install a kW/kWh meter to separately measure production.

3. All service provided by the Company under this and all other schedules is governed by the rules and regulations approved by the MPSC.

Issued .... (Date) By Jack Haffey (Signature of Officer of Utility)

Approved .... (Date) Effective .... (Date)

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PUBLIC SERVICE COMMISSION OF MONTANA.

.... Secretary.

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Form 43-B

Public Service Commission of Montana

The Montana Power Company
(Name of Company)

Sheet No. LTPP-82
Cancelling Sheet No. None
Page 1 of 3

Schedule LTPP-82

Long-Term Power Purchase Service

AVAILABILITY: To any Seller who operates facilities for the purpose of generating long-term electric energy in parallel with the Company's system. This schedule is applicable to Cogeneration and Small Power Production (COG/SPP) facilities that are Qualifying Facilities under the Rules of the MPSC.

DEFINITIONS: "Seller," for purposes of this schedule, is any individual, partnership, corporation, association, government agency, political subdivision, municipality, or other entity that:

1. Operates a qualifying COG/SPP facility;

2. Has signed the standard written contract with the Company stipulating the terms and conditions of the interconnection and sale of electricity to the Company;

3. Has agreed in the standard contract to provide electricity to the Company on a long-term basis as defined in the contract.

"Company" means The Montana Power Company.

"MPSC" means The Montana Public Service Commission.

"Contract Year" means twelve months beginning on July 1.

RATE: Energy: $0.0409/kWh

Capacity: The Seller will be compensated monthly for capacity according to the following formula:

$$\text{\$/Annual Contract kW/month} = \frac{\$6.74 \times ACCF}{.85}$$

where: ACCF = Annual Contract Capacity Factor

Annual Capacity Payment Adjustment: At the end of each Contract Year, a reconciliation of the accumulated monthly capacity payments made to the Seller for the Contract Year and actual capacity value to the Company for the Contract Year will be made utilizing the following formula:

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Approved ____________ (Date) Effective ____________ (Date)

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PUBLIC SERVICE COMMISSION OF MONTANA.

Form 403-B

Public Service Commission of Montana

The Montana Power Company — Sheet No. LTPP-82

Cancelling Sheet No. None

Name of Company)

Schedule LTPP-82

Long-Term Power Purchase Service

$$\$/AAKW = \frac{(\$80.92 \times ACCF)}{(\quad .85 \quad)} \times \frac{(AACF)}{(ACCF)} \times \frac{(AAKW)}{(ACKW)}$$

Refund to Company = (Dollars Paid to Seller) - ($/AAKW)(AAKW)

where: AAKW = Annual Actual kW (for Contract Year)
ACCF = Annual Contract Capacity Factor
AACF = Annual Actual Capacity Factor (for Contract Year)
ACKW = Annual Contract kW
If AAKW is greater than ACKW then AAKW = ACKW

Special Terms and Conditions:

1. Change of Rate: This schedule will be reviewed annually for each Contract Year and revised upon MPSC approval.

2. Net Billing Option: (A) If the Seller opts for Long-Term Net Billing in the standard contract and the Seller's consumption kWh exceeds the production kWh, the Seller will be billed for only the consumption kWh in excess of production kWh according to the Company's applicable Retail Sales Rate Schedule. If the Seller's consumption kWh is less than the production kWh, the Seller will receive payment for only the production kWh in excess of consumption kWh according to the energy rate in this schedule.

(B) To meet the conditions of this Option and to receive a separate capacity payment, the Seller's consumption must be measured and billed on a demand basis and a separate kW/kWh meter to measure production is required. Under this Option, the Seller will be billed at the Company's applicable Retail Sales Rate Schedule for only the consumption kW in excess of the production kW. If the Seller's production kW exceeds the consumption kW, the Seller will be compensated for only the production kW in excess of the consumption kW according to the Production Capacity Payment Procedure detailed in this Schedule. The calculation of monthly capacity payments for the expected excess production kW will utilize the expected annual net production capacity factor. The Annual Capacity Payment

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Approved .... (Date) Effective .... (Date)

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Form 603-B

Public Service Commission of Montana

The Montana Power Company
(Name of Company)

Sheet No. LTPP-82
Cancelling Sheet No. None
Page 3 of 3

Schedule LTPP-82

Long-Term Power Purchase Service

Adjustment is to be applied to the actual excess production kW for the Contract Year. The procedure will utilize the annual contracted and annual actual gross production kW and gross capacity factor information for payment reconciliation.

3. All service provided by the Company under this and all other schedules is governed by the rules and regulations approved by the MPSC.

Issued ______ (Date) By ______ (Signature of Officer of Utility)

Approved ______ (Date) Effective ______ (Date)

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PUBLIC SERVICE COMMISSION OF MONTANA.

PACIFIC POWER & LIGHT COMPANY

SCHEDULE NO. 87
PURCHASES FROM COGENERATORS AND SMALL POWER PRODUCERS

AVAILABLE:
For qualifying facilities located in the territory served by Company in Montana.

APPLICABLE:
To all non-utility owners or operators of qualifying facilities (Sellers) who are willing and able to enter into a written contract.

DEFINITIONS:
Qualifying Facility means either a cogeneration facility or small power production facility not greater than 80 megawatts capacity as defined hereunder:

(a) Cogeneration Facility means a facility which produces electric energy together with steam or other forms of useful energy (such as heat) which are used for industrial, commercial, heating or cooling purposes through the sequential use of energy.

(b) Small Power Production Facility means a facility which produces electric energy using as a primary energy source biomass, waste, renewable resources, or any combination thereof.

CONDITIONS OF SERVICE:
All purchases shall be accomplished according to the terms and conditions of a written contract.

RATES FOR SALES:
All sales by Company to Sellers shall be in accordance with standard rate schedules filed by Company with the Commission.

RATES FOR PURCHASES:
The rates for purchases by Company hereunder shall be either 1) the Short-Term Rate or 2) the Long-Term Rate, at the option of the Seller exercised at the time of execution of a written contract at:

1) Short-Term Rate

a) All energy purchased is to be priced, at the option of the Seller, exercised at the time of execution of a written contract at i) the Average Rate or ii) the Time Differentiated Rate.

(Continued)

Issued 6/29/82 Fredric D. Reed Effective on and after

Issued by PACIFIC POWER & LIGHT COMPANY
Fredric D. Reed, Vice President and Treasurer
Public Service Building, Portland, Oregon

SCHEDULE NO. 87
PURCHASES FROM COGENERATORS AND SMALL POWER PRODUCERS

RATES FOR PURCHASES: (Continued)

i) Average Rate

2.28¢ per kwh

ii) Time Differentiated Rate

On-Peak: 6 a.m. to 10 p.m. Monday through Friday
2.76¢ per kwh for all kwh purchased during the On-Peak period.

Off-Peak: All other times.
1.84¢ per kwh for all kwh sold during the Off-Peak period.

b) Term of Contract: Not less than one (1) year.

2) Long-Term Rate

a) Availability: Available to all Sellers willing to sign a written contract with a term of not less than four years.

b) All energy and contracted capacity is to be priced, at the option of the Seller, exercised at the time of execution of the contract, at i) the Average Rate or ii) the Time Differentiated Rate.

i) Average Rate

A) Energy Payment

4.99¢ per kwh

B) Capacity Payment

($7.21 per kw per month) x (dcf) for all contracted kw, where (dcf) represents the Demonstrated Capacity Factor pursuant to the terms and conditions of a written contract.

(Continued)

SCHEDULE NO. 87
PURCHASES FROM COGENERATORS AND SMALL POWER PRODUCERS

RATES FOR PURCHASES: (Continued)

ii) Time Differentiated Rate

A) Energy Payment

On-Peak: 6 a.m. to 10 p.m. Monday through Friday.
6.05¢ per kwh for all kwh sold during On-Peak periods.

Off-Peak: All other times.
4.03¢ per kwh for all kwh sold during Off-Peak periods.

B) Capacity Payment

All times
($7.21 per kw per month) x (dcf) for all contracted kw, where (dcf) represents the Demonstrated Capacity Factor pursuant to the terms and conditions of a written contract.

RULES AND REGULATIONS:
Service hereunder is subject to the General Rules and Regulations contained in the Company's regularly filed and published tariff and to those prescribed by regulatory authorities.

STATE OF MONTANA
ELECTRIC RATE SCHEDULE

MONTANA DAKOTA UTILITIES CO.
400 NORTH FOURTH STREET
BISMARCK, NORTH DAKOTA 58501

MPSC Volume
1st Revised Sheet No
Cancelling Original Sheet No

SHORT TERM POWER PURCHASE - RATE STPP-92

AVAILABILITY:

To any qualifying cogeneration and small power production (COG/SPP) operating facilities for the purpose of generating short-term electric energy in parallel with the company's system. This schedule is applicable to cogeneration and small power production facilities that are Qualifying Facilities under the Rules of the Montana Public Service Commission.

RATE:

Energy: 2.16¢/Kwh

TERMS AND CONDITIONS:

1. Change of Rates: This schedule will be reviewed annually for each Contract Year and revised upon the Commission's approval.

2. The rates and terms and conditions set forth herein are subject to the provisions of the "Net Billing Option," and "Interconnection Cost Amortization Option" set forth in Rates 94 and 95, respectively.

3. The company shall install appropriate metering facilities to record all flows of energy necessary to bill and pay in accordance with the charges and payments contained in this rate schedule.

4. The customer shall, with prior written consent of the company, furnish, install and wire the necessary service entrance equipment, meter sockets, meter enclosure cabinets, or meter connection cabinets that may be required by the company to properly meter usage and sales to the company.

5. The term of the contract hereunder shall be at least twelve months but less than four years.

6. A standard written contract with the company has been signed stipulating the terms and conditions of the interconnection and sale of the electricity to the company.

7. All services provided by the company under this and all other schedules are governed by the rules and regulations approved by the Montana Public Service Commission.

Issued July 7, 1982 (Date) By C. Wayne Fox
Assistant Vice President

(SPACE BELOW THESE LINES FOR USE OF COMMISSION ONLY)

Approved July 16, 1982 (Date)
Docket No. 81.2.15; Order No. 4865b
(Space for Stamp or Seal of Commission)

Effective for electric service rendered on and after (Date) July 16, 1982

PUBLIC SERVICE COMMISSION OF MONTANA

STATE OF MONTANA
ELECTRIC RATE SCHEDULE

MONTANA-DAKOTA UTILITIES CO.
400 NORTH FOURTH STREET
BISMARCK, NORTH DAKOTA 58501

MPSC Volume
1st Revised Sheet No
Cancelling Original Sheet No. 2n

LONG TERM POWER PURCHASE - RATE LTPP-93

AVAILABILITY:
To any qualifying cogeneration and small power production (COG/SPP) facilities for the purpose of generating long-term electric energy in parallel with the company's system. This schedule is applicable to cogeneration and small power production facilities that are Qualifying Facilities under the Rules of the Montana Public Service Commission.

RATE:
Energy: 5.23¢/Kwh

Capacity: The Seller will be compensated monthly for Capacity according to the following formula:

$$\$/\text{Annual Contract Kw/month} = \frac{\$5.33 \times ACCF}{.85}$$

where: ACCF = Annual Contract Capacity Factor

Annual Capacity Payment Adjustment: At the end of each Contract Year, a reconciliation of the accumulated monthly Capacity payments made to the Seller for the Contract Year and actual Capacity value to the company for the Contract Year will be made utilizing the following formula:

$$\$/AAKW = \frac{(\$63.96 \times ACCF) \times (AACF) \times (AAKW)}{(\ \ .85\ \ ) \times (ACCF) \times (ACKW)}$$

Refund to Company = (Dollars Paid to Seller) - ($/AAKW) (AAKW)

where: AAKW = Annual Actual Kw (for Contract Year)
ACCF = Annual Contract Capacity Factor
AACF = Annual Actual Capacity Factor (for Contract Year)
ACKW = Annual Contract Kw
If AAKW is greater than ACKW then AAKW = ACKW

Issued July 7, 1982 (Date) By C. Wayne Fox, Assistant Vice President

(SPACE BELOW THESE LINES FOR USE OF COMMISSION ONLY.)

Approved July 16, 1982 (Date)
Docket No. 81.2.15; Order No. 4865b

Effective for electric service rendered on and after July 16, 198_ (Date)

PUBLIC SERVICE COMMISSION OF MONTANA
Madeline L. Cottrill

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STATE OF MONTANA
ELECTRIC RATE SCHEDULE

MONTANA-DAKOTA UTILITIES CO.
400 NORTH FOURTH STREET
BISMARCK, NORTH DAKOTA 58501

MPSC Volume [illegible]
1st Revised Sheet No [illegible]
Cancelling Original Sheet No. [illegible]

TERMS AND CONDITIONS:

1. Change of Rates: This schedule will be reviewed annually for each Contract Year and revised upon the Commission's approval.

2. The rates and terms and conditions set forth herein are subject to the provisions of the "Net Billing Option," and "Interconnection Cost Amortization Option" set forth in Rates 94 and 95, respectively.

3. The company shall install appropriate metering facilities to record all flows of energy necessary to bill and pay in accordance with the charges and payments contained in this rate schedule.

4. The customer shall, with prior written consent of the company, furnish, install and wire the necessary service entrance equipment, meter sockets, meter enclosure cabinets, or meter connection cabinets that may be required by the company to properly meter usage and sales to the company.

5. The term of the contract hereunder shall be four years or more.

6. A standard written contract with the company has been signed stipulating the terms and conditions of the interconnection and sale of the electricity to the company.

7. All services provided by the company under this and all other schedules are governed by the rules and regulations approved by the Montana Public Service Commission.

Issued July 7, 1982 (Date)

By Assistant Vice President

(SPACE BELOW THESE LINES FOR USE OF COMMISSION ONLY)

Approved July 16, 1982 (Date)

[D]ocket No. 81.2.15; Order No. 4865b

Effective on and after (Date) July 16, 198

PUBLIC SERVICE COMMISSION OF MONTANA

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Chapter V

HYDROELECTRIC EQUIPMENT

This chapter provides an overview of the type of turbines and electrical equipment which are relevant to small hydro projects. This material is intended for use in determining equipment alternatives at the reconnaissance level of project development.

TURBINES*

The capacity of a hydroelectric site is determined by water flow and the available head. Selection of the type of turbine needed to drive an electric generator is based primarily on the head. Table V-1 gives the range of operational heads for several types of turbines. Propeller turbines with adjustable-pitch blades - also known as Kaplan turbines - are useful where flows vary widely. Several manufacturers have developed other small turbines, such as rim-type and crossflow-types, which have special characteristics that might be preferred for some projects. The most common types of turbines are shown in Figure V-1. Typical efficiency curves for various types of hydraulic turbines are shown in Figure V-2.

Table V-1. Types of Turbines Used for Various Heads

Turbine	Operational Head
Lift Translator	Low: less than 0.5 m to 15 m (1.5 ft to 50 ft.)
Tube-type	Low: less than 25 m (80 ft)
Impulse-or Pelton-type	High: greater than 60 m (200 ft)
Vertical Propeller-type	Low to Medium: 4.6 m to 60 m (15 ft to 200 ft)
Francis-type (horizontal or vertical)	Low to High: 9.4 m to 400 m (30 ft to 1300 ft)

* Turbine information and descriptions contained in this chapter were obtained from the California Department of Water Resources publication entitled: Small Hydroelectric Potential at Existing Hydraulic Structures in California Bulletin 211, April 1981 (See Reference V-1).

Types of Turbines

Francis Turbines. A Francis turbine has fixed vanes. Water enters the turbine in a radial direction on a plane perpendicular to the turbine-generator shaft, then changes direction 90 degrees, and is discharged in an axial direction, parallel to the shaft. The principal components of the turbine are a water spiral supply case to carry water to the runner, the runner itself, wicket gates to control the amount of water reaching the runner and to distribute it equally around the runner, and a draft tube to carry the water away from the turbine. The turbine can be mounted either vertically or horizontally depending on site conditions.

The Francis turbine can operate over a range of about 20 to 110 percent of its design flow. The peak efficiency of about 88 to 92 percent usually occurs at about 75 to 95 percent of its rated flow. Below 75 percent of its rated flow, the turbine's efficiency drops fairly rapidly to about 80 percent at 50 percent of its rated capacity (Figure V-2).

Propeller Turbines. A propeller-type turbine has a runner with three to six blades. The water passes through the runner in an axial direction parallel to the shaft. The principal components of the propeller turbine are similar to those of a Francis turbine. The pitch of the blades can be either fixed or adjustable; adjustable blades permit the turbine to operate with greater efficiency over a wider range of water flows.

Propeller turbines can be mounted either vertically or horizontally. Vertical propeller turbines are available for heads ranging from 4.6 m to 61 m (15 ft to 200 ft). Propeller turbines can be operated over a range of about 10 to 100 percent of their design flow if provided with adjustable blades. Peak efficiency of 85 to 90 percent occurs at 80 to 95 percent of the rated flow for variable pitch (Kaplan) units. Fixed blade propeller units peak with roughly the same efficiency as variable pitch units at the same relative flow rate. Below 90 percent of the rated capacity, turbine efficiency will drop off more rapidly than with the variable pitch propeller turbine to about 40 percent at 50 percent of the rated capacity (Figure V-2).

Tube-type Turbines. Tube-type turbines are horizontal or slant-mounted propeller runners with the electric generator located outside the water-supply case. This arrangement is accomplished using an S-shaped water passageway that includes the intake valve or gate, turbine, and draft tube as a single unit with the turbine-generator shaft extending out of the tube at the top bend of the S-shape. Tube-type turbines can have either fixed or adjustable blades. The performance characteristics for a tube-type turbine are similar to those for propeller turbines.

Tube-type turbines can be connected to the generator either directly or through a speed increaser gear box. The speed increaser lowers the plant's efficiency but allows the generator to be physically smaller with a corresponding reduction in manufacturing cost. The choice of direct or speed-increaser coupling is an economic decision. The advantages of using a speed increaser gear box is greater with lower heads.

Standardized tube-type turbines are available in sizes ranging up to a 5000 kW capacity and for heads of 1.8 m to 25 m (6 ft to 80 ft). The use of a tube-type turbine is generally limited to a maximum head of 15 m to 25 m (50 ft to 80 ft).

Bulb Turbines. A bulb turbine is a horizontal propeller-type unit whose generator is contained in a bulb immersed in the flow of water within the water-supply case. The bulb, held in place by structural supports, is provided with access shafts for maintenance. The performance characteristics of bulb turbines are similar to those of tube-type turbines with about a one percent improved efficiency since the flow of water is in a straight line rather than changed in direction by the S-shape.

The bulb turbine's compact design reduces the size of the powerhouse needed but introduces the need for additional structural supports to position the bulb within the water-supply case. Access to the generating unit for maintenance is more difficult than with other types of turbines. The bulb turbine is available from foreign manufacturers and has been used successfully in low-head hydroelectric installations in Europe.

Rim Turbines. The rim-type turbine is similar to the bulb turbine except that the generator rotor is mounted on the periphery of the turbine runner blades. The concept was developed by a Swiss manufacturer 40 years ago and given the name "Straflo". About 80 units presently in service have capacities ranging from 100 KW to 25 MW at heads of 1 to 38 meters (3 to 125 feet). The rim design requires a water sealing arrangement between the water-supply case and the rotating outer rim.

The performance characteristics of the rim-type turbine are similar to those of the bulb turbine. The rim-type design is simple and compact, requires less civil works and a smaller power house than other types of turbine/generators.

Impulse Turbines. An impulse turbine (also known as a pelton wheel) uses one or more nozzles to direct water at the buckets of a runner in a nonpressurized space. Impulse turbines are used for installations with heads above about 45.7 m (150 ft). Unless the head is greater than several hundred feet, the other types of turbines are likely to result in a lower-cost installation. The design and installation of an impulse turbine for high-head hydropower is relatively simple with lower maintenance than for other types of turbines. The unit consists of one or more nozzles, each with a needle valve, a one-piece cast runner and a direct-connected electric generator. No draft tube is required.

Impulse turbines have very flat efficiency curves and may be operated down to loads of 10 percent of their rated capacity (Figure V-2).

Cross-flow Turbines. The cross-flow turbine is a variation of the impulse turbine. The cross-flow turbine has a cylindrical runner with adjustable inlet-guide vanes to direct the flow of water, and a conical draft tube. The draft tube creates a pressure below one atmosphere in the runner chamber, thereby using the head between the runner centerline and the tailrace water level. This head is lost in impulse turbine installations.

The performance characteristics of the cross-flow turbine are similar to those of an impulse turbine; it has a very flat efficiency curve over a wide range of flow conditions. However, the peak efficiency of the cross-flow turbine is 83 to 85 percent as compared with an 88 to 92 percent efficiency with other types of turbines(Figure V-2).

Schneider Lift Translator. A relatively new turbine design, referred to as the "Schneider Lift Translator", has been developed and may be applicable to certain low-head projects. The Schneider Lift Translator is still in the research and development stage, but several prototypes are being manufactured for trial installation as a part of a U.S. Department of Energy (DOE) grant. Basically, the Schneider device resembles a series of venetian blinds mounted in a somewhat oval shape. It has the potential to produce power under very low-head conditions. The trial installations will attempt to use it in existing conduits. A lift translator was recently installed on an irrigation canal in Richvale (Butte County), California.

The basic lift translator design operates with heads between 0.5 m (1.5 ft) and 15.2 m (50 ft), and has a capacity of 1 kW to 50 kW. Other units are available for higher heads and higher capacities of up to 5000 kW.

GENERATORS AND ELECTRICAL EQUIPMENT*

The generator converts the mechanical energy of the turbine into electrical energy. Generators have two main components: the rotor and the stator. The rotor is the rotating assembly to which the mechanical torque of the turbine shaft is applied. By magnetizing or "exciting" the rotor, a voltage is induced in the stationary component, or the stator. The speed of the generator is determined by the turbine selection, except where geared with a speed increaser. In general, for a fixed value of power, a decrease in speed will increase the physical size of the generator and the cost of the machine.

There are two types of generators: synchronous and induction type. Following is a brief presentation of the operations and advantages of each.

Synchronous Generators

The synchronous generator is so named because it is synchronized to the power grid's voltage and frequency before the breaker device which connects the generator to the system is closed. When connected, it continues to operate at synchronous speed.

The excitation of the generator is achieved by applying a direct current source across the rotor field coils and creating a magnetic field within the stator which induces a voltage potential in the stator coils. This can be accomplished either with a static excitation device or with a brushless shaft driven exciter. The brushless exciter is a rotating a.c. generator with rectifiers on the main shaft used to produce d.c. current for the field.

The voltage regulator functions as an automatic control device. It

*Portions of the material in this section were taken from the publication: Small Hydroelectric Systems: A Guide to Development in California, California Energy Commission, September 1981, (See Reference V-2).

senses machine voltage and compares it to a set point. As the generator load changes, the voltage regulator adjusts the machine excitation to hold the generator voltage constant.

To place a synchronous generator on line, synchronizing gear is used. The excitor-regulator first brings the machine up to system voltage. The synchonizing gear matches frequency and phase with the system and then the generator is connected to the grid. In order to maintain synchronous speed and provide stable power when a load is placed on the system, a governor is used. The governor, often called a "load follower", regulates the load on the turbine by controlling the inlet water valves. This in turn controls the speed of the generators to match electrical load demands. Governors can be either hydraulically or electrically operated, depending on system needs.

Synchronous generators have the advantage of operating independently of the grid, since they are self-excited and self-regulating. However, such machines are complex and relatively expensive, and a developer may find a project using an induction generator economically more attractive.

Induction Generators

The induction or asynchronous generator is somewhat simpler than the synchronous type. Induction generators operate initially as induction motors, taking their excitation from the grid, and are brought up to synchronicity by the grid. Speed deviation above or below synchronous speed, termed "asynchronous operation", determines whether energy is absorbed or supplied by the machine. Because the induction generator can be easily paralled with the grid, the need for synchronizing equipment is eliminated. Because these generators are simpler and less expensive, they are particularly attractive for smaller projects, usually those under one megawatt.

Generator and Line Circuit Breakers

Generator and line circuit breakers are the link that connects the generator to the power grid. The generator circuit breaker closing occurs when the unit is in synchronism with the power grid. These circuit breakers also act as an interrupting or tripping mechanism to disconnect the unit from the system when either an abnormal condition occurs or for a normal shutdown.

Circuit breakers are classified by type, voltage class, continuous rated current and interrupting capacity. Some single unit plants eliminate the generator circuit breaker and connect the plant to the system with the for station service power must be added. The line circuit breaker is located on the high voltage side of the step-up transformer in the switchyard. Vacuum and gas type are being installed more frequently due to decreased maintenance costs. However, many utilities still standardize designs for small installations around the oil type unit. Standard voltage levels are 15,500, 38,000, 48,300, 72,500 and 121,000 volts.

For the various type breakers, control cabinets and consoles are available for the circuitry required to close and trip the breaker. Options include relaying equipment and key interlocks.

Transformers

The power transformer is a device which efficiently steps the voltage from generation level to transmission level. Efficiencies are generally in the range of 99 percent. For small hydroelectric installations, a single two winding, oil-filled substation type transformer is used. The main tank is pressurized with nitrogen to preserve the dielectric strength of the insulating oil. High and low pressure switches protect against failure of the gas cushion which also provides for temperature expansion of the oil. Connections to the transformer are insulated by porcelain bushings, which may be supplied with current transformers for metering, relaying and instrumentation.

Relaying Equipment and Surge Protection

An important part of hydroelectric plant operations deals with safety and protection. In particular, short circuits and ground faults within the plant must be monitored and corrective action must be initiated to prevent injury to personnel or damage to equipment. The plant must be isolated equipment.

Surge protection is required for the generator. This protection consists of capacitors and lightning arresters located as close to the generator terminals as possible to prevent insulation damage or flashing over on the generator windings. The breakdown voltage of the surge protection is well below the insulation level of the windings and effectively protects against induced overvoltages, potential rise in event of a fault, and lightning or switching surge overvoltages on the transmission line. Protective relaying must be provided to immediately shut down the various equipment under fault conditions and for other abnormal events. The primary relaying for generators and transformers consists of differential relays which operate on an unbalance of the currents in and out of the protected equipment and are extremely high speed devices. Zones of protection of the relays for the generators and transformers should overlap. The generators are also protected by overcurrent relays for each phase and neutral and by undervoltage and overvoltage relays. Phase and neutral relay contacts are generally paralleled to pick up an auxiliary relay for tripping of an associated circuit breaker. Less critical equipment such as auxiliary transformers do not warrant the expense of differential schemes and can be adequately protected by overcurrent relays.

Switchyard

The switchyard is comprised of line circuit breakers, if used, or fuses, disconnect switch, transformers, structures, buswork and miscellaneous power plant equipment. The arrangement of this equipment should allow for the future maintenance of circuit breakers and other major equipment with minimum effect on de-energizing buswork and other equipment. For single unit small hydroelectric installations, the switchyard will consist of the generator bus or cable, step-up transformer, a disconnect switch, a line circuit breaker or fuse and a take-off tower. Station transformers, excitation transformers, and surge and metering cubicles may also be included in the switchyard to decrease floor space requirements in the powerhouse structure.

Plants having capacities in the range of up to about 1 MW, could conceivably have the switchyard reduced to a singly guyed pole having both the lightning arresters and switch pole mounted circuit breakers. The transformer, if required, could be either of the dry type and pad mounted inside the plant or an outdoor type pole mounted.

The location of the switchyard with respect to the powerhouse is dependent on site conditions, space requirements and topography. Where feasible, the best location of the switchyard is close to the powerhouse structure. This eliminates costly extension of the generator bus and reduces power losses in the bus.

Interconnection Versus Independence From Grid (Micro-Hydro Projects

For small hydro projects of less than about 100 Kw the type of equipment, the kind of project, and its economics all depend largely upon whether the project is to be lined to the grid, or whether energy production is directed only to local consumption. As noted in the chapter dealing with regulatory matters, a license, or exemption from the licensing process, is required from the Federal Energy Regulatory Commission whenever a project is connected to the electrical grid.

The savings from avoiding the licensing process and grid tie-in changes can be economically attractive to small projects where the benefits of selling power to a utility are not decisive for project success.

Independence from the power grid allows for the use of a direct current generator. With a direct current generator the individual can either use the direct current as is, or convert it to alternating current when needed through the use of an inverter. Such a system offers the flexibility of either using the power for conventional a.c. appliances, or storing the power as direct current in batteries. This is optimum for very small systems (less than about 5 kilowatts). In addition, a d.c. system is not speed-sensitive, and so no governor is needed. Battery storage used in conjunction with small hydroelectric have an advantage over those used in conjunction with other alternative energy sources such as wind power, since a hydro generator will operate, except in the more extreme cases, more consistently. This means that a deep discharge condition, common with wind systems, is rare. Deep discharge is a common cause of battery failure. However, it should be pointed out that the storage function can limit the size of the d.c. system as battery requirements increase.

However, there are distinct advantages of being tied to the grid. These advantages are related in part to the question of load control. Hydro units connected to the power grid can use the grid as a storage function; this is accomplished by putting excess power (i.e. power in excess of developers' local need) into the grid and taking it back when local demand exceeds supply. Where there is no access to the grid, the load control units must dispose of the excess power. Such units usually dump excess energy as heat, which can often be used for supplementary space or water heating. Within such a system, load control equipment is usually required to turn key equipment on and off on a priority basis as demand rises and falls in relation to output.

If a project is to be connected to the grid, equipment will be required which will protect the hydro project, as well as the grid itself. Interconnection agreements are normally signed between the project operators and the utility purchasing energy and capacity from the project, thus providing for proper control of generator voltage, current, and frequency. The control and protective equipment protects both the generator and the distribution system from damage, should either fail, and supplies a means of safely isolating the generator from the distribution line should there be an electric disturbance or emergency. Such items normally form part of the negotiations for sale of power.

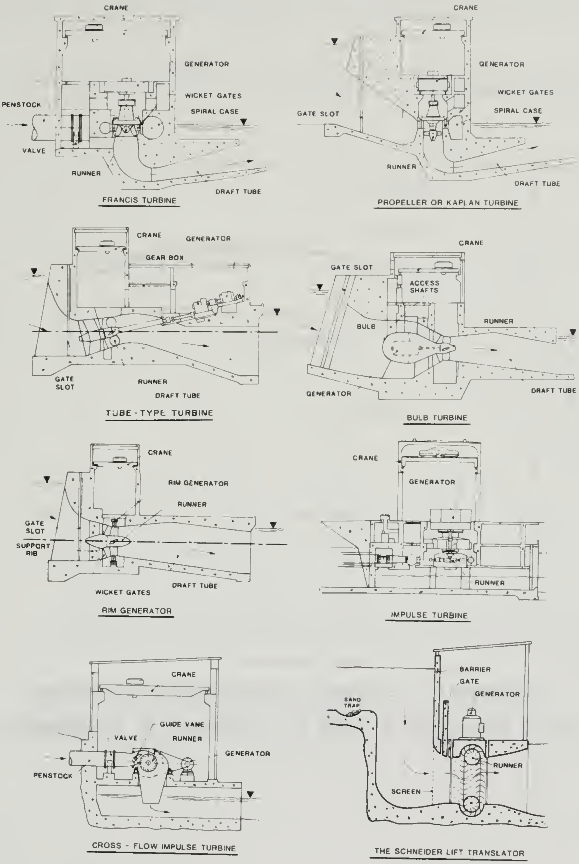

FIGURE V-1 TYPES OF TURBINES

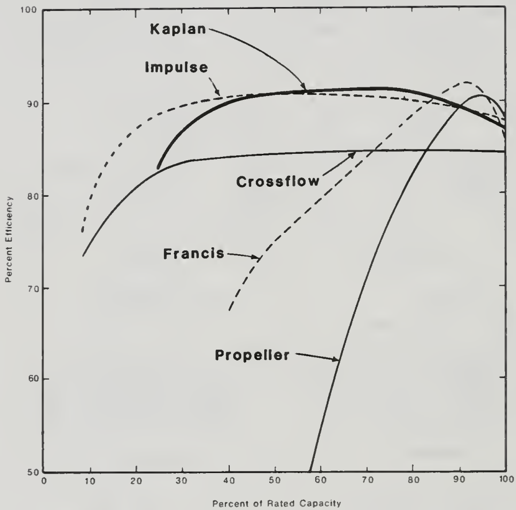

FIGURE V-2 TYPICAL EFFICIENCY CURVES FOR VARIOUS TYPES OF HYDRAULIC TURBINES

REFERENCES - CHAPTER V

V-1 Small Hydroelectric Potential At Existing Hydraulic Structures in California, Bulletin 211, April 1981, available from California Dept. of Water Resources, Box 388, Sacramento, CA 95802.

V-2 Small Hydroelectric Systems: A Guide to Development in California, California Energy Commission, 1111 Howe Avenue, Sacramento, CA 95825, September, 1981.

Chapter VI

PROJECT LAYOUT[1]

This chapter describes major components involved in small hydro projects together with typical layouts for several types of systems. This material should prove useful during site reconnaissance by suggesting possible design alternatives and identifying primary system components. After alternatives have been screened, a more detailed engineering design can be carried out for use in evaluating project feasibility.

HYDRAULIC SYSTEM COMPONENTS

A general discussion of major components for small hydro systems is presented below. It should be noted that the actual final design for a particular site may include additional or alternative items depending on specific site conditions. Several of these components are illustrated in Figure VI-1.

Diversion Structure

In most cases it will be necessary to build some type of obstruction in the stream to divert flow into a canal or pipeline. Usually this diversion structure will be a relatively small (6 to 8 feet high) dam with a gated transition to the pipeline or canal. The location of the upstream diversion will probably depend on several economic considerations. In general, since power is proportional to the product of flow and head, moving the diversion point upstream will increase the amount of power only as long as the head increases faster than the flow decreases. It is not, however, always advantageous to place the diversion at the point of maximum power potential. For an upstream diversion site, the increase in power must offset increased costs due to the longer length of pipe required and possible increased ice protection at the inlet at high altitudes. Therefore, the preferred project location is determined by evaluating the trade-offs between increased power revenue and increased pipeline costs.

Intake and Trashrack

The intake structure controls the flow of diversion water into a penstock or diversion conduit. Trashracks are usually provided on the

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[1] Much of the descriptive and graphical material used in this chapter has been taken directly from References VI-1 and VI-2.

intake to prohibit debris and ice from entering and damaging the turbine runner. Trashracks should be sloped so that rakes can be easily used to clean ice and debris from racks. The bar spacing should be close enough to restrict the passage of any object that might not safely pass through the turbine, and yet not cause undue headloss.

Flow regulation gates can also be located on the intake structure. Flow velocity into the intake, through trashracks and gate openings, should be in the range of about 2 to 3 ft/sec. At these velocities some clogging of the trashrack can occur without an excessive decrease in head on the turbine. The intake shape should follow a transition to the entrance of the penstock diversion conduit. The intake and transition should be reasonably smooth and without sudden enlargements, expansions, or sharp edges.

If the gates at the intake are used for emergency closure, then provisions must be made downstream of the gates for air admission to the water conduit. Air may be admitted through a gate shaft, vent or automatic vacuum breaker valves.

For intakes where ice formation may be a problem, it may be required to include electric heating in the gate slots to ensure the gates may be closed at any time. Also, compressed air may be used to keep ice free from the trashrack by use of a bubbler system at the base of the trashracks and upstream of the racks to break up the ice and allow its removal.

A fish screen, is a device intended to prevent fish from being swept into the turbine. If required such a screen may eliminate the need for a separate trashrack. The maximum allowable opening is on the order of 1/8-inch, depending on location. Screens of this size tend to plug easily unless continuously cleaned by sweep mechanisms.

Diversion Conduit

The diversion conduit in the form of a canal or low-pressure pipeline brings water from the diverson structure to the penstock. By constructing the diversion conduit along a very flat gradient water can be transported from the diversion to a point directly above the powerhouse with very little head loss. A relatively short section of high pressure penstock is then used to convey water down to the powerhouse. It is generally much less expensive to run a canal or low pressure pipeline along the hillside to a short section of penstock than it is to install a long high-pressure penstock from the diversion to the powerhouse. In addition, a more stable system results due to the relative ease of controlling a turbine that is fed by a shorter penstock.

The decision to use either a pipe or a canal depends on a number of factors. Pipes have less leakage than unlined canals and, if clogged with debris, will not overflow and erode the surrounding area. A pipeline is not as accessible to the public as a canal and will generally require less maintenance. A buried pipe may be preferred in some cases. For sites where canals are cost effective they can be designed for relatively low head losses and sufficient freeboard to absorb surges from the penstock. A canal can also be used as a sedimentation trap although extra cleaning problems may result.

Penstock

The penstock is the pressure conduit which conveys water to the turbine. Normally the penstock is made of steel but it can be constructed of concrete, wood, PVC, or can even be a pressure tunnel terminating at the powerhouse.

Proper design and construction of a penstock are extremely important. Large forces exerted by the weight and momentum of the water (as well as other factors) usually require the use of reinforced concrete anchors to stabilize individual pipe sections. Because penstocks usually are installed on steep slopes,soil stability and safety from land slides must also be considered. It may also be necessary to take into account factors such as thermal expansion and contraction, outside coating, and cathodic and lightning protection.

Regardless of the material used for the penstock, the effects of "water hammer" must be considered in the penstock design. Water hammer is a change in the internal pressure, either above or below the normal pressure, which is caused by a sudden change in the rate of water flow. Any sudden load change in the turbine/generator can change the water demand and, if the turbine gates open or close rapidly, water hammer will occur in the penstock. If the turbine gates close rapidly, a positive water hammer pressure is produced and, conversely, rapid gate opening results in a negative pressure surge. The penstock must therefore be designed to withstand the combined effect of hydrostatic pressure and positive water hammer pressure without rupturing and also not collapse under a negative pressure surge. "Relief valves" or "surge tanks" are commonly used to confine the effects of water hammer to the penstock.

Valves and Gates

Under normal operating conditions, the flow of water through reaction turbines is controlled by either the turbine wicket gates, by adjustable blading of the turbine runner, or, in the case of impulse turbines, by deflecting the nozzle jet away from the turbine runner or adjusting the needle valve setting. A valve or gate is usually placed ahead of the turbine to control the water flow during shut-down, start-up, and maintenance operations. Valves of the ball, plug or butterfly type or wheel-mounted gates may all be used. None of these closure devices are normally used for flow modulation and their usual use is in either the fully open or fully closed position.

Powerhouse

The powerhouse contains the turbine, generator, and controls, and must be properly designed and constructed to ensure a smoothly functioning project. Location of the powerhouse may be a critical factor in overall project layout. To maximize the power output, the powerhouse should be built as close to the level of the receiving water (tailrace) as possible. However, this benefit must be balanced against the potential for flood damage. Structures located on the outside of a bend of a stream are more likely to suffer damage from floating debris during a flood than those located on the inside of a bend. In narrow canyons, a powerhouse installation can create an obstruction in the floodway which forces the flood water elevations to levels higher than historical records would indicate. In some cases, it is possible to put the machinery floor just above the tailwater level while designing the building to be water-tight to an elevation above the expected flood level. This can be difficult and costly since the powerhouse must be made heavy enough not to float during a flood, and the walls must be made waterproof. Usually, with this method, all electrical equipment with the exception of the generator, is placed on a second floor, above the flood level. The benefits which balance these additional costs are an increase in the available head and, for reaction turbines, a reduction in the chances of cavitation.

Miscellaneous Power Plant Equipment

Small hydro installations are generally not operated by on-site personnel and therefore are usually only designed to house generating equipment. Other types of equipment which may or may not be required include the following:

Ventilation. A central blower located in the roof or walls with temperature control to actuate when ambient temperature rises above 74°F (23°C) is normally provided. Filtered air inlets near the floor at generator level are also included.

Water System. A duplex pump system with strainers, taking water from the tailrace, may be needed for water-cooling requirements of the turbine/ generator bearings. Water taken from the penstock can be used for backup. The cooling water system should operate independently of the plant generating equipment.

Crane. A permanent powerhouse crane is not recommended for small hydroelectric plants. Due to size and cost of equipment, it is considered more economical to bring in portable equipment for major plant overhauls. A portable gantry crane for larger power plants may be provided which would include crane rails embedded in the generator deck and an electrical power connection. Appropriate hatches should be provided for access for removing any equipment located below grade which may require removal for maintenance or replacement.

Fire Protection. A CO_2 fire protection system could be employed in the generator housing assembly and general plant area. The purpose of such a system is to extinguish fires that occur within the generator housing. A common physical configuration is a bank of cylinders against a wall with discharge headers and piping to the generator housing for the initial and delayed discharge systems. Small hydroelectric installations may not warrant automatic fire systems. Local hand-operated CO_2 extinguishers may be suitable. However, for unattended plants the time lag involved because of non-automatic operation must be considered. If the CO_2 system is automatic, then provisions have to be made to remove any discharged gas that may collect inside the powerhouse structure prior to any entry by personnel.

Drainage. A sump for collecting all drainage water within the powerhouse is constructed at the lowest elevation within the powerhouse. In addition, either draft tube gates or stop logs at the end of the draft tube may be installed to isolate the draft tube from the tailrace for dewatering. Electric driven sump pumps, automatically controlled by sump water level, remove the collected water and discharge it at an acceptable point.

Tailrace. The tailrace is the water channel that transports the water discharged from the turbine to a reservoir, canal or river. This structure must be designed to prevent erosion of downstream embankment or channel. If the tailrace is to terminate in a river or streambed, it is advisable to determine the maximum and minimum surface elevation of the river or stream at the powerhouse site. At high river flows, the powerhouse site may require special flood protection.

TYPICAL LAYOUTS

Various system configurations and powerhouse layouts are discussed in this section. It should be emphasized that these examples are quite general and may not necessarily apply to any one particular site. Final decisions regarding individual project layouts must take into consideration actual site conditions.

Much of the following information has been taken directly from Reference VI-2 and includes illustrations of project layouts for different types of hydropower developments. It is entirely possible that alternative types of turbine units to those shown in Figures VI-1 & 2 could be utilized.

High Head Layout

This type of project will probably involve an upstream diversion structure and a lengthy penstock terminating at the powerhouse (see Figure VI-1). An impulse turbine, crossflow or other type of high head turbine will most likely be utilized. The powerhouse will likely be located near an existing stream channel or canal. Difficult construction problems may occur if powerhouse is located in a steep canyon where working space is limited.

Canal Drop Layout

This type of development is possible where water can be diverted from an existing canal and transmitted through a penstock to a powerhouse located downslope. An existing stream bed or channel is also necessary to convey water from the powerhouse downstream. Operation of the canal-type small hydro system will normally require some form of coordinated control over the canal intake gates in order to meet both the small hydro and the previously existing water demands. No unusual difficulties should be encountered in constructing the project but special provision may have to be made if the canal cannot be dewatered during construction. The penstock for this layout may require a butterfly valve just upstream of the powerhouse and a slide gate in the intake structure (See Figure VI-2A).

Concrete Dam Layout

A small hydro development of this type may be constructed downstream of a new or existing concrete arch, gravity, or buttress dam. Where the dam already exists the cost of development will normally be reduced by utilizing an existing outlet works conduit as part of the penstock. Connection to an existing outlet works conduit can usually be completed without incurring major costs. Construction of the powerhouse in most locations requires that the area be cofferdammed off to a level that provides adequate protection against flooding (See Figure VI-2B).

Earthfill Dam Layout

This type of development is similar to Type B (Fig. VI-2) in that the utilization of an existing outlet works conduit could reduce the project cost. Many earthfill dam outlet works, however, have the outlet regulating valve location near the centerline of the dam cross-section with the downstream section of the conduit unpressurized and free flowing. If the downstream section is not of sufficient strength a new section of penstock may have to be placed inside the existing conduit downstream of the regulating valve. The existing valve should also be checked to determine if it is desirable for power production. Construction of the powerhouse is similar to that required for Type B (See Figure VI-2C).

POWERHOUSE LAYOUT

Figures VI-3 through VI-6, illustrate typical powerhouse layouts for several types of turbine installations. This material is intended mainly for informational use, as the final powerhouse design should be determined based on equipment manufacturers' recommendations and site-specific conditions.

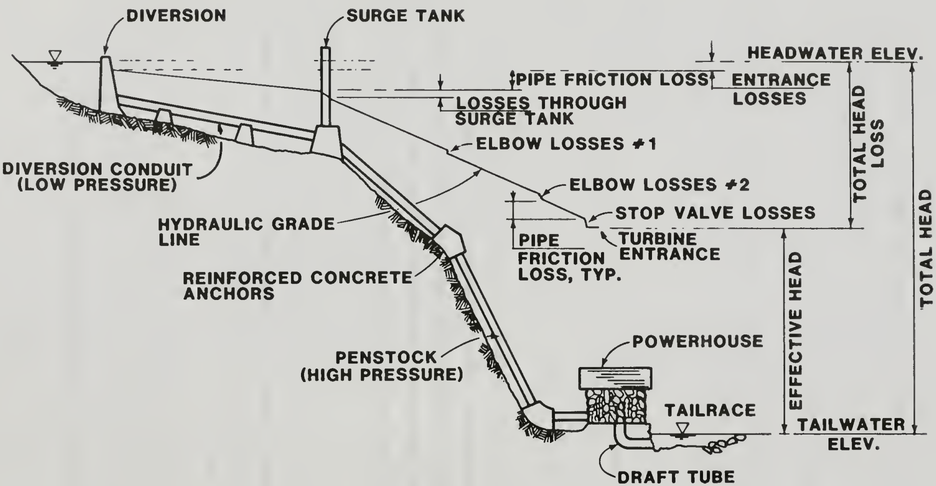


FIGURE VI-1
TYPICAL HIGH HEAD INSTALLATION

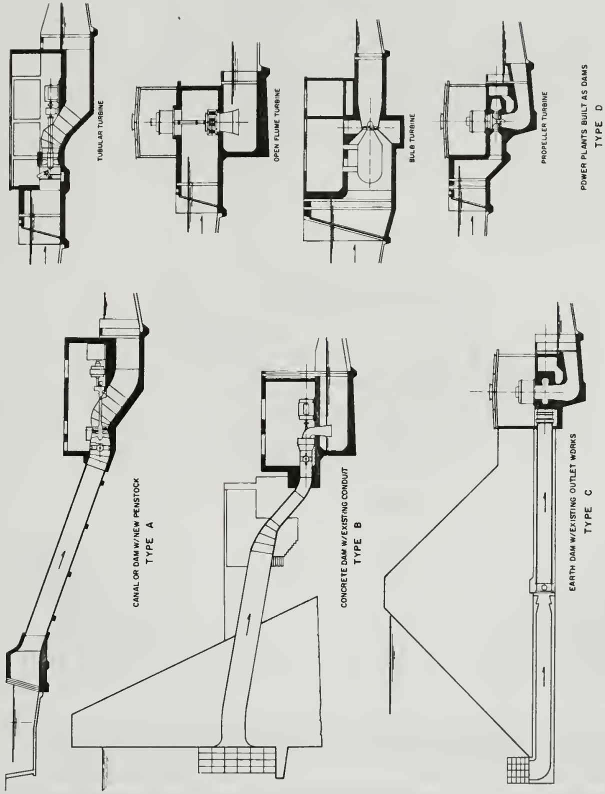
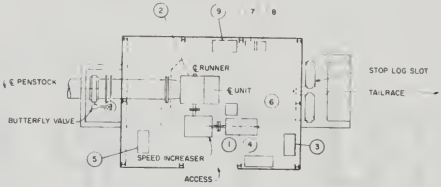
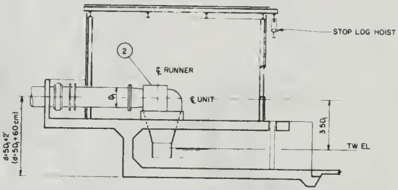


FIGURE VI-2
STANDARD PROJECT TYPES

TUDOR



PLAN



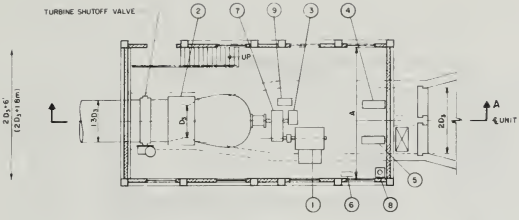
SECTION A

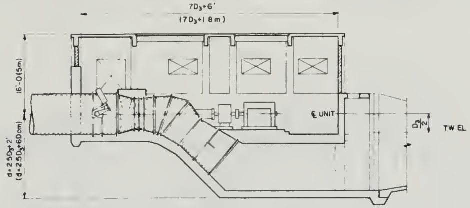
Equipment
1. Generator
2. Turbine
3. Governor
4. Generator Breaker
5. Control Panel
6. Neutral Ground Cubicle
7. Cooling Pumps
8. Sump Pumps
9. Air Compressor and Tank

NOTES:
1. Arrangement and equipment are schematic.
2. Layout, equipment and dimensions shown may vary according to site specific power plant conditions.
3. Powerhouse area given in Fig. 5-20.

TUDOR

FIGURE VI-3
POWERHOUSE LAYOUT--CROSSFLOW TURBINE



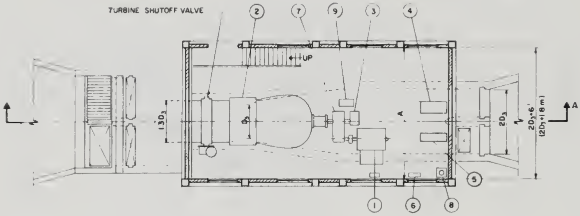


Equipment
1. Generator
2. Turbine
3. Governor
4. Generator Breaker
5. Control Panel
6. Neutral Ground Cubicle
7. Speed Increaser
8. Sump Pumps
9. Pressure Set

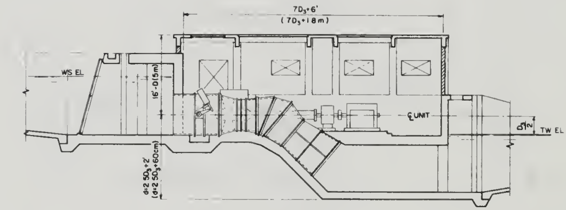
NOTES:
1. Arrangement and equipment are schematic.
2. Layout, equipment and dimensions shown may vary according to site specific power plant conditions.
3. Powerhouse area given in Fig. 5-16.

FIGURE VI-4 POWERHOUSE LAYOUT-- TUBULAR TURBINE WITH PENSTOCK

TUDOR



PLAN



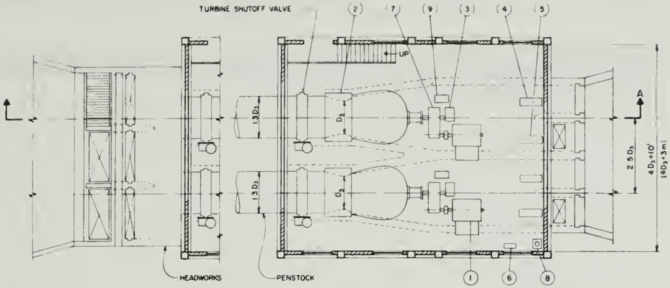
SECTION A

Equipment
1. Generator
2. Turbine
3. Governor
4. Generator Breaker
5. Control Panel
6. Neutral Ground Cubicle
7. Speed Increaser
8. Sump Pumps
9. Pressure Set

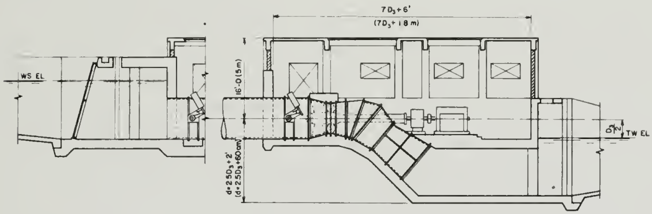
NOTES:
1. Arrangement and equipment are schematic.
2. Layout, equipment and dimensions shown may vary according to site specific power plant conditions.
3. Powerhouse area given in Fig. 5-17.

FIGURE VI-5 POWERHOUSE LAYOUT-- TUBULAR TURBINE WITH HEADWORKS

TUDOR



PLAN



Equipment
1. Generator
2. Turbine
3. Governor
4. Generator Breaker
5. Control Panel
6. Neutral Ground Cubicle
7. Speed Increaser
8. Sump Pumps
9. Pressure Set

SECTION A

NOTES:
1. Arrangement and equipment are schematic.
2. Layout, equipment and dimensions shown may vary according to site specific power plant conditions.
3. Powerhouse areas given in Figs. 5-16 and 5-17.

FIGURE VI-6 POWERHOUSE LAYOUT-- TUBULAR TURBINE, MULTIPLE UNITS

TUDOR

REFERENCES - CHAPTER VI

VI-1. Building and Operating a Small-Scale Hydroelectric Power Plant, Course Syllabus for Continuing Education Short Course presented by University of California at Berkeley, January 27-28, 1982.

VI-2. Reconnaissance Evaluation of Small, Low-Head Hydroelectric Installations, Water and Power Resources Service, Denver, Colorado, Prepared by Tudor Engineering Company, July 1, 1980.

Chapter VII

HYDROLOGY AND POWER GENERATION POTENTIAL

SITE HYDROLOGY

Development of information concerning the magnitude and variation of streamflows at a proposed site is essential in order to determine the proper size and type of power plant. The characterization of flows can be made with varying degrees of sophistication, depending largely on the availability and type of data. The developer should first determine if streamflow records have at any time been kept for the stream or canal in question. Inquiries regarding streamflow records should begin with the U. S. Geological Survey (Federal Building, Helena, MT 59620), although flow records are occasionally kept by such agencies as the Forest Service, U.S.D.A. Soil Conservation Service, and Montana Department of Fish, Wildlife and Parks.

If historic flow records are not available, the developer should immediately begin a program of streamflow monitoring at the development site. Methodology for making streamflow measurements is outlined in Reference VII-1. Measurements should be taken often enough to determine a sequence of representative streamflows for the development site and should be continued throughout the early phases of project development. By so doing, several years of flow records may well be acquired prior to final project design. After subtracting minimum streamflow requirements these flows can then be used to accurately determine the potential installed capacity of the hydropower facility and the energy which can be developed therefrom.

Annual Hydrograph

Information essential to the analysis of site power potential includes a typical annual hydrograph for the development site. Such a hydrograph is plotted using either daily, weekly, or monthly flow values, depending on what data are available for the site. Once obtained, an annual hydrograph can be used to identify periods of high and low flows as well as the frequency of large fluctuations in flow. This information is necessary to foresee the annual hydropower generation pattern likely to result from the particular site. Knowledge of this generation pattern, together with the flow-duration curve analysis discussed in the following section may be important factors in negotiating a power sales agreement with the local utility.

Flow-Duration Curves

Of the various ways in which streamflow data can be used to assess power potential, the flow-duration approach is perhaps the most widely used as well as most easily understood. A flow duration curve (see Figure VII-1) is a graph showing the percent of time during some total period that the flow rate of a stream can be expected to equal or exceed any specified flow rate. Flow magnitudes as well as the shape of the flow duration curve are extremely important in determining hydroelectric power potential for a particular site. The development of flow duration curves for ungaged locations in Montana is discussed in the Appendix.

Capacity Factor

Once the flow-duration curve has been developed for a site and a reliable design flow established it becomes possible to estimate the "capacity factor" for the proposed hydropower plant. The capacity factor is the ratio of the energy that a plant actually produces to the energy that would be produced if it were operated at full capacity throughout a given period, usually a year.

Computation of the capacity factor for projects where both head and flow vary significantly involves the following steps. First, the expected average annual power production in kilowatt-hours must be estimated by one of the methods described on pages VII-5 and 6. This is then divided by the number of kilowatt-hours which would be produced if the plant were to be operated at rated capacity for a year. This computation determines an estimate of the "average" capacity factor to be expected for the installation. If the plant is built on a free-flowing stream, the "actual" capacity factor resulting from plant operation will vary from year to year (sometimes significantly) depending on variation in streamflow. If the facility is operated with constant head and constant flow rate the capacity factor should not change significantly.

For the situation where the available head does not vary significantly with discharge, the average capacity factor can be computed directly from the flow-duration curve by determining the area under the curve at a particular exceedence Q value, then determining the area corresponding to the condition of the plant being operated at full capacity 100 percent of the time. The capacity factor would then be determined by dividing the first area by the second (See Figure VII-2 for calculation of capacity factor corresponding to "Q_{30}", the 30th percentile flow).

SYSTEM DESIGN AND POWER COMPUTATIONS

The decision regarding the sizing of a hydropower facility (i.e. chosing the design flow, design power output, penstock diameter, etc.) will be governed in part by the shape of the flow-duration curve and the operating characteristics of the particular turbine chosen for use. If it is desired to generate power over a wide range of flow values, multiple turbine-generator units may be needed. The design flow may also be influenced by legal and institutional factors, for example, a particular power sales agreement may favor sizing the facility to obtain a specified capacity factor. Minimum streamflow requirements at the site along with minimum cut off flow requirements for different turbines may also influence design decisions. Several small hydro projects, which are currently being developed in California, are being sized for flows in the range between Q_{15} and Q_{20} on the flow duration curve. That is to say the design flow or greater can be expected 15 - 20% of the time.

Power Computation

The two main quantities involved in computing the power potential at a site are the streamflow rate "Q" and the effective head "H". The design flow for the installation, as discussed in the previous paragraph, is used along with effective head to calculate the maximum power potential for the site. The effective head is conceptually equal to the gross head (H_G) minus all head losses in the diversion conduit and penstock. Head losses for the system may be estimated (assuming values for conduit length, diameter and frictional resistance) using Eq. VII-2 and VII-3 in the following section. Gross head is the elevation difference between the water surface at the point of diversion and the free water surface at the point of discharge from the powerhouse. For a reaction turbine, the discharge free water surface is the tailwater surface at the exit of the draft tube; for an impulse turbine it is at the elevation of the discharge nozzle.

Power computations are made using the following equation:

$$P = \frac{QH}{11.8} \qquad \text{(Eq.VII-1)}$$

where P = power (kw), Q = flow rate (cfs), H = effective head (ft), and 11.8 is a conversion factor. In this form, Eq. VII-1 represents the power available to the turbine. If the right-hand side of Equation VII-1 is multiplied by the combined efficiency of the turbine-generator, then the result will be the actual power production.

Power Vs. Flow

Once the design flow has been determined, a series of hydraulic calculations can be made to estimate the actual power output to be expected for a given flow rate through the penstock. Such calculations are useful in assessing the effects of penstock material and diameter on system performance. The following steps are involved:

1) Determine desired system design flow or power output
2) Estimate gross head and penstock length
3) Choose penstock material and the corresponding resistance coefficient (C) determined from Table VII-1
4) Assume penstock diameter
5) Compute head loss due to friction (h_f) from the Hazen-Williams equation:

$$h_f = \frac{LQ^{1.85}}{(1.318C)^{1.85}\, R^{1.17}\, A^{1.85}} \qquad \text{(Eq. VII-2)}$$

where:

h_f = frictional head loss (ft)

C = resistance coefficient

L = penstock length (ft)

R = hydraulic radius (ft); for a circular conduit flowing completely full R equals the penstock diameter divided by 4

A = penstock cross-sectional area (sq ft)

Q = flow rate (cfs)

6) Compute minor losses resulting from: pipe fittings, valves, trash rack, etc.

$$h_m = \frac{KQ^2}{64.4\, A^2} \qquad \text{(Eq. VII-3)}$$

where:

h_m = minor head loss (ft)

K = minor loss coefficient (see Table VII-1)

A = cross sectional area of the penstock immediately upstream from fitting (sq ft)

7) Sum head loss due to friction and minor losses to obtain total head loss

8) Find effective head, H, (sometimes referred to as "net head") available for power generation:

$$H = \text{gross head} - \text{total head loss}$$

9) Compute power output, P, (KW)

$$P = \frac{QHe}{11.8} \qquad \text{(Eq. VII-4)}$$

where:

Q = flow rate (cfs)

H = effective head (ft)

e = turbine-generator efficiency (if turbine-generator efficiency curves are not available, total efficiency values in the range .60 - .80 are reasonable estimates

10) Steps 3-9 can be repeated to determine the effects of penstock diameter and roughness on system power output. As a general rule, designing the penstock for a velocity of about 10 feet per second will tend to minimize both penstock head loss and cost. After penstock characteristics have been finalized, the calculations in steps 1-9 can be used to develop a graph of power output versus flow through the system as well as a graph of net head versus flow rate. Such graphs are useful in the calculation of annual energy production as presented in the following section.

<u>Annual Energy Calculation</u>

For the case of a small hydro system operating under constant head and flow conditions (i.e. a system operating from a canal or diversion structure) the total annual energy production (in kilowatt hours) is given by:

$$\text{Annual Energy} = \frac{QHeN}{11.8} \quad \text{(N = number of hours of plant operation during the year)} \qquad \text{(Eq. VII-5)}$$

If the flow rate and net head for a system vary significantly during annual operation then estimates of average annual energy production can be made using either of the two methods outlined below:

Method I - Annual Hydrograph Approach: The graph of P vs Q determined from the computation procedure involving Equations VII-2 through VII-4 can be used together with the annual hydrograph to estimate annual energy production. This procedure is illustrated in Figure VII-3 which shows how individual hydrograph flows are used to determine corresponding values of power in kilowatts. Each flow value comprising the hydrograph has a definite time interval (i.e., daily, weekly, monthly, etc.). Individual flow values are chosen from the hydrograph and used to determine the corresponding power values from the P vs Q curve. Once the power values have been determined they are multiplied by the number of hours in the time interval to convert to units of energy. For example, if daily flow values are used then the corresponding daily energy (kilowatt hours) is obtained by multiplying power values by 24 hours. The total annual energy is obtained by summation of the individual daily energy values for the year.

Method II - Duration Curve Approach: The flow-duration curve for the hydro power site can be also used to estimate average annual energy production. The procedure involves first transforming the flow-duration curve into a power-duration curve, followed by conversion of average annual power into average annual energy. The procedure for developing the power-duration curve is shown in Figure VII-4 and assumes that a "total efficiency curve" for turbine and generator is available. If this is not the case then the P vs Q graph cited in Method I can be used in place of the H vs Q graph and the Efficiency vs Q graph.

Once the power-duration curve has been obtained it becomes necessary to determine the average power (kw). This is accomplished by measuring the area under the power-duration curve over the entire range of potential power production. This area, which is the average power produced during the year, is multiplied by the number of hours of actual plant operation per year to obtain average annual energy in kilowatt-hours. In computing the area under the power duration curve the "percent exceedence" scale must first be converted from percent to equivalent decimal fractions. For example the area under the power-duration curve in Figure VII-4 can be found (approximately) by subdividing the total area into rectangles or squares which can then be totaled. If rectangles are chosen having a vertical dimension of 200 kw and a horizontal dimension of .2 it is found that about 12.5 such rectangles comprise the total area under the curve. The average power in this case would be found as the product of 12.5 X 200 X .2 which comes out to be 500 kw.

Resistance Coefficients and Minor Loss Coefficients

Pipe Material	Resistance Coefficient "C"
Concrete (regardless of age)	130
Cast iron	
New	130
5 yr old	120
20 yr old	100
Welded steel, new	120
Wood Stave (regardless of age)	120
PVC	140
Asbestos - Cement	140
Riveted Steel, new	110

Pipe Fitting	Minor Loss
Trash Rack	.1 ft @ 1 ft/sec., .5 ft @ 2 ft/sec.
	Minor Loss Coefficient "K"
Penstock entrance loss	.1 smooth entrance
	.5 square entrance
Bends in Penstock	.2 @ 45°, .3 @ 90°
Valves	
gate valve	.2
needle valve	.2
butterfly valve	.25

*After Water Resources Engineering, Linsley & Franzini, Third Ed., McGraw-Hill

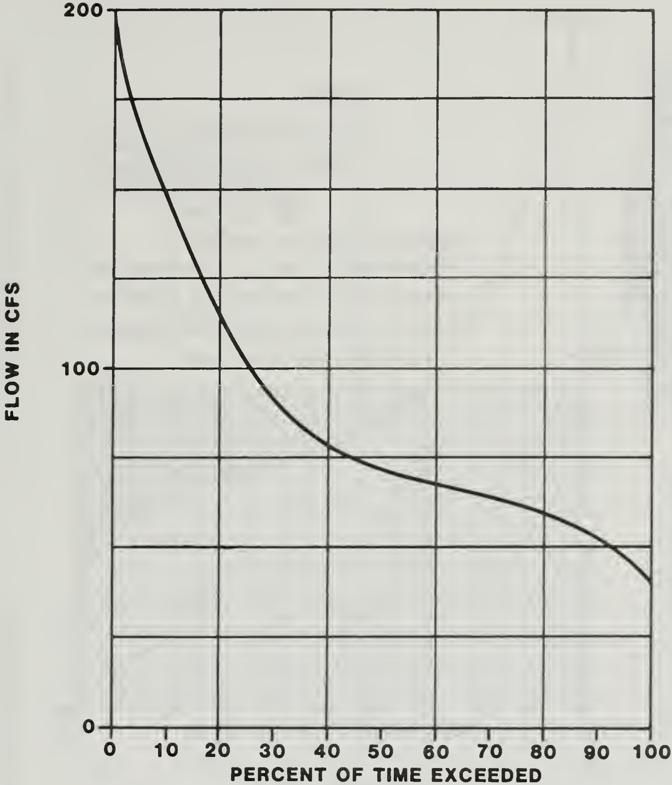


FIGURE VII-1
TYPICAL FLOW-DURATION CURVE

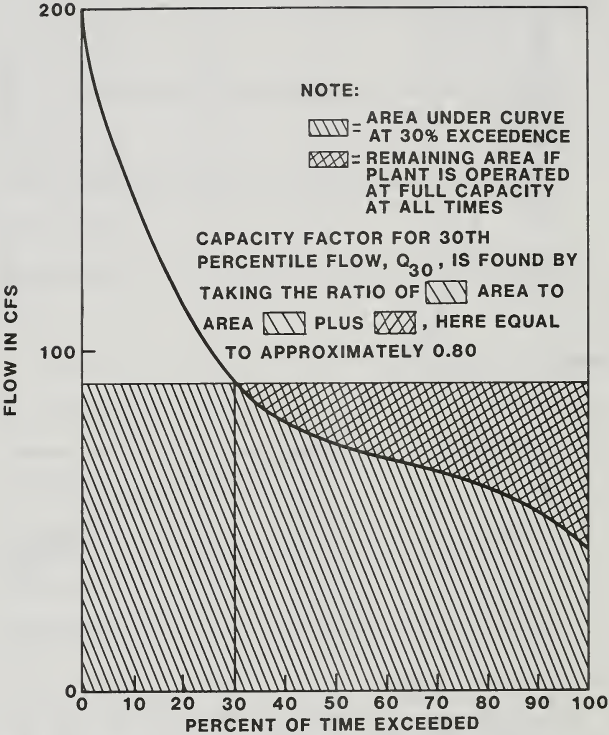
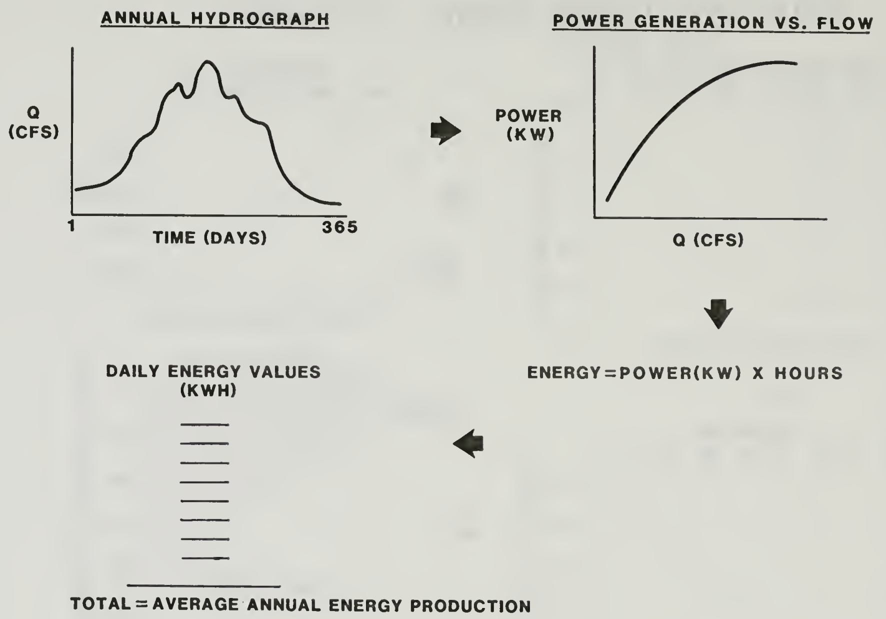


FIGURE VII-2

CAPACITY FACTOR COMPUTATION



(METHOD I)

FIGURE VII-3
AVERAGE ANNUAL ENERGY PRODUCTION CALCULATION

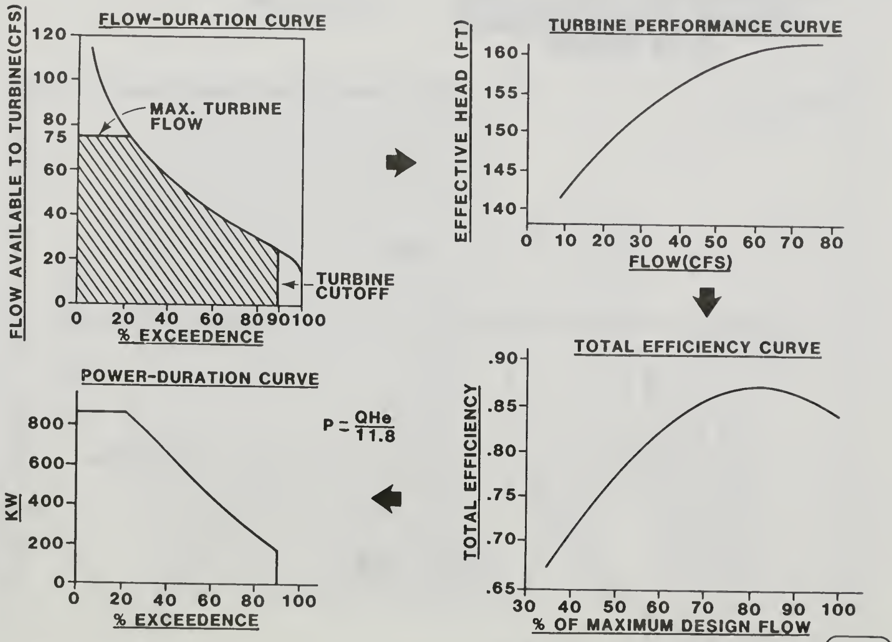


FIGURE VII-4
ANNUAL ENERGY CALCULATION
(METHOD II)

REFERENCES CHAPTER VII

VII-1 General Procedure for Gaging Streams, by R. W. Carter and Jacob Davidson, Series on Techniques of Water Resources Investigations of the U. S. Geological Survey, Chapter A6, For Sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

VII-2 Water Resources Engineering, Linsley & Franzini, Third Ed., McGraw-Hill San Francisco.

Appendix

FLOW DURATION CURVE SYNTHESIS

If a hydropower site is located on an ungaged stream, it is extremely important that a program of periodic streamflow measurement be undertaken at the beginning of project feasibility assessment. By so doing, several years of flow records, representative of conditions at or near the point of diversion may be accumulated prior to final project design. In the absence of adequate on-site flow data methods, a procedure for synthesizing approximate flow-duration curves may sometimes be used. One such method, which has been developed for Columbia River Basin tributaries in Montana, is outlined below.

A regional study of hydrologic characteristics for the Columbia River Basin in Montana was recently completed by Montana State University[1] and has resulted in the development of a method for synthesizing flow duration curves for ungaged locations. This procedure consists of formulating so-called "dimensionless flow-duration curves" using streamflow records from gaged streams in a particular region. Flow-duration curve ordinates are obtained for these gaged streams and each ordinate is then divided by the Q_{10} value thereby producing ordinates which are dimensionless. All dimensionless flow-duration curves for a given region are then plotted on a single graph and, if their shapes are similar, a single average curve is chosen. The shape of the final average dimensionless flow-duration curve is then assumed to be representative for all streams in the region. The dimensionless curve is then "scaled" to an ungaged site using parameters (including drainage area and mean annual precipitation) determined from maps and graphs. The end product of this procedure is an estimate of the actual flow-duration curve for the ungaged site. The accuracy of this procedure will vary depending on the degree of hydrologic similarity between the ungaged site and the gaged sites used to develop dimensionless curves. The dimensionless flow-duration curve procedure may be applied to any site located in the Columbia River Basin in Montana. Locations outside this basin cannot be addressed at this time, although

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[1] Cunningham, A. B., "A Resource Survey of Hydroelectric Potential in the Columbia River Basin in Montana," Montana University Joint Water Resources Center, September 1980.

research is presently underway to extend flow-duration curve synthesis techniques to cover all of Montana. Findings from this investigation will be available by late 1983 through the Montana Water Resources Research Center, MSU Campus, Bozeman, MT 59717.

Steps involved in the dimensinless flow-duration curve synthesis procedure are as follows:

Step 1: Locate the ungaged site on a topographic map (U.S. Geological Survey 7 1/2 minute maps are recommended, if available) and delineate the drainage area above point of diversion. Areas should be measured in square miles.

Step 2: Estimate the average annual precipitation, in inches, for the drainage area using the annual precipitation map series in Figures A-1 through A-4. If the drainage basın is overlain by more than one precipitation contour then the average value may be obtained from:

$$P_{AVG} = \frac{\sum_{i=1}^{N} P_i A_i}{A_t} \qquad \text{Eq. A-1}$$

where: P_{AVG} = Average annual precipitation (inches)

A_i = Portion of drainage area assumed to be representative of the "P_i" precipitation contour.

A_t = Total drainage area (Note that $\sum_{i=1}^{N} A_i$ must equal A_t)

N = Number of precipitation subareas.

Step 3: Using the average annual precipitation from Step 2 determine the average annual runoff, in inches, from Figure A-5.

Step 4: Convert average annual runoff into "cfs" units using the following equation:

$$Q_{AA} = .0737\ A_t R \qquad \text{Eq. A-2}$$

where: Q_{AA} = Average annual flow (cfs)

A_t = Total drainage area (sq. mi.)

R = Average annual runoff (inches)

.0737 = Factor converting sq. mi. inches per year into cfs.

Step 5: Estimate the 10% exceedence flow, Q_{10}, from the following empirical equations developed for use in the different regions of the Columbia River Basin as defined in Figure A-6:

$$Q_{10} = CQ_M \qquad \text{Eq. A-3}$$

where C is defined as:

Region	"C" Value
1	2.84
2	3.03
3	3.18
4 Blackfoot-Clark subdrainage	2.68
Bitterroot subdrainage	3.04

Step 6: From Figures A-6 through A-8 select the dimensionless flow duration curve range which is representative of the region containing the hydropower site location. The dimensionless flow duration curve is drawn in this range in accordance with site specific factors. If the site is on a small mountain stream, the curve should be drawn at the bottom of the range, corresponding to rapid runoff conditions. The top curve of each range corresponds to large drainages with slow times of concentration. The ordinates of the ungaged flow-duration curve are determined by multiplying each dimensionless curve ordinate by the value of Q_{10} obtained in Step 5.

Example:

Consider a site on Williams Creek which feeds the Tobacco River in Northwestern Montana. From a U. S. Geological Survey topographic map the drainage area was delineated and precipitation contours were drawn directly on the topographic map. The drainage area was found to be 8.0 sq. mi. and the weighted average precipitation was calculated to be 46.9 in/yr. From the Precipitation-Runoff graph in Figure A-5 the average annual runoff was estimated to be 29 in/yr assuming an alpine-rocky terrain. Q_{AA} was then computed to be 17.1 cfs. The value of Q_{10} was found to be 49 cfs using the coefficient for Region 1 (Step 5). The particular dimensionless flow-duration curve chosen for this location appears at the lower edge of the range describing Region 1 in Figure A-7. The ordinates for the Williams Creek site were found by multiplying the dimensionless curve ordinates by Q_{10} as follows:

	$\frac{Q_{10}}{Q_{10}}$	$\frac{Q_{20}}{Q_{10}}$	$\frac{Q_{30}}{Q_{10}}$	$\frac{Q_{40}}{Q_{10}}$	$\frac{Q_{50}}{Q_{10}}$	$\frac{Q_{60}}{Q_{10}}$	$\frac{Q_{70}}{Q_{10}}$	$\frac{Q_{80}}{Q_{10}}$	$\frac{Q_{90}}{Q_{10}}$
Dimensionless flow duration curve ordinates	1	.47	.26	.18	.14	.12	.10	.08	.07

	Q_{10}	Q_{20}	Q_{30}	Q_{40}	Q_{50}	Q_{60}	Q_{70}	Q_{80}	Q_{90}
Williams Creek flow-duration curve ordinates (cfs)	49	23	13	8.4	6.9	5.9	4.9	3.9	3.4

Prepared by USDA Soil Conservation Service in cooperation with Montana Department of Natural Resources and Conservation, Water Resources Division.

USDA SCS PORTLAND OR 1977

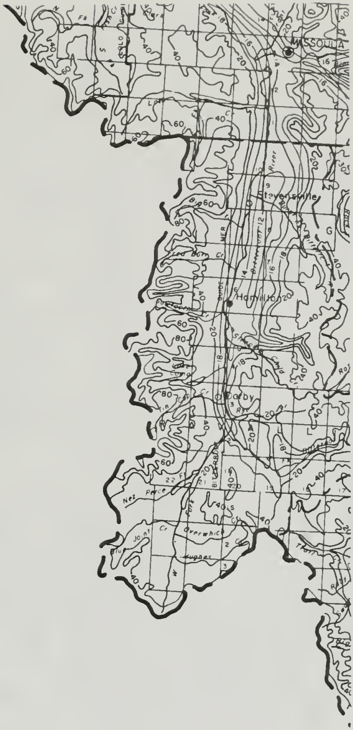
Scale: 1 inch equals approx. 16 miles
STATE OF MONTANA
AVERAGE ANNUAL PRECIPITATION
IN INCHES
1941 - 70 Base

FIGURE A-1

Prepared by USDA Soil Conservation Service in cooperation with Montana Department of Natural Resources and Conservation, Water Resources Division.

Scale: 1 inch equals approx. 16 miles
STATE OF MONTANA
AVERAGE ANNUAL PRECIPITATION
IN INCHES
1941 - 70 Base

FIGURE A-2



LEGEND

State Boundary

County Boundary

HELENA — State Capital

Philipsburg — County Seat (small town)

Prepared by USDA Soil Conservation Service in cooperation with Montana Department of Natural Resources and Conservation, Water Resources Division.

USDA SCS PORTLAND OR 1977

Scale: 1 inch equals approx. 16 miles
STATE OF MONTANA
AVERAGE ANNUAL PRECIPITATION
IN INCHES
1941 - 70 Base

FIGURE A-3

Prepared by USDA Soil Conservation Service in cooperation with Montana Department of Natural Resources and Conservation, Water Resources Division.

Scale: 1 inch equals approx. 16 miles
STATE OF MONTANA
AVERAGE ANNUAL PRECIPITATION
IN INCHES
1941 - 70 Base

FIGURE A-4

USDA SCS PORTLAND OR 1977

AVERAGE ANNUAL RUNOFF VS. AVERAGE ANNUAL PRECIPITATION

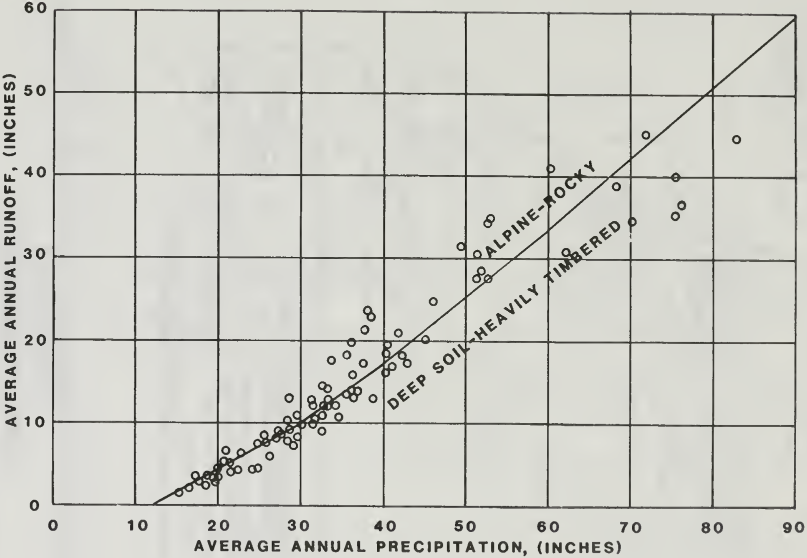


FIGURE A-5

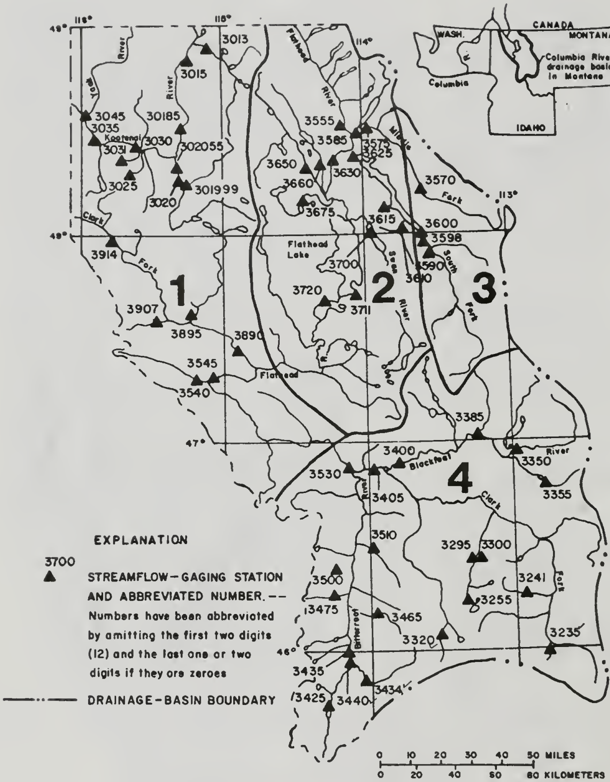
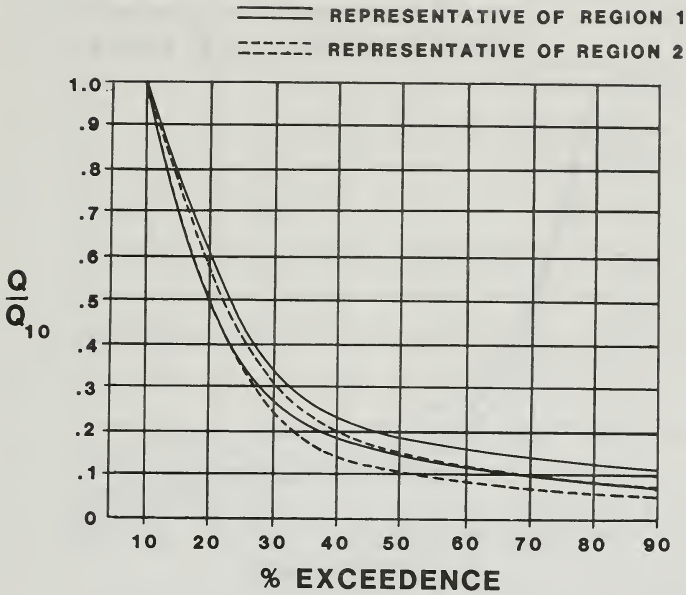


FIGURE A-6

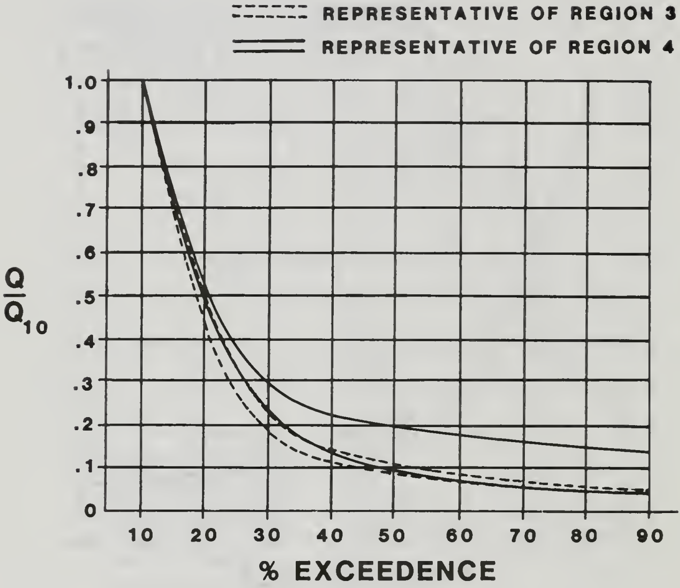
AREAS OF INFLUENCE OF

DIMENSIONLESS FLOW DURATION CURVES



DIMENSIONLESS FLOW DURATION CURVES

FIGURE A-7



DIMENSIONLESS FLOW DURATION CURVES

FIGURE A-8

ACRE-FOOT (ac-ft, AF) -- The amount of water required to cover one acre to a depth of one foot. This is equivalent to 325,851 gallons, 43,560 cubic feet, 1,233.5 cubic metres, or 1.2335 cubic dekametres.

ADVERSE WATER CONDITIONS -- Water conditions that limit the hydroelectric generation by either a low water supply or a reduced HEAD.*

ALTERNATING CURRENT (ac, AC) -- Electricity that reverses its direction of flow periodically, as contrasted to DIRECT CURRENT.

AMORTIZATION -- The paying of a debt with installment payments or with a sinking FUND. Also writing off expenditures by prorating them over a period.

APPRAISAL STUDY -- A preliminary feasibility study made to determine if a detailed FEASIBILITY STUDY is warranted. Also called a reconnaissance study.

AVAILABILITY FACTOR -- The percentage of time a plant is available for power production.

AVERAGE-WATER YEAR -- The average annual flow of water available for hydropower generation calculated over a long period, usually 10 to 50 years.

AVOIDED COST -- The payment made for the capacity and energy of a small power project; such payment equals the cost to a utility of obtaining and operating additional generating units, or to purchase power from another source, if this power were not available. Also called avoidable cost.

BARREL (bbl) -- The measure used for crude oil; it is equal to 42 U.S. gallons (gal).

BARREL-OF-OIL EQUIVALENT -- (BOE). A unit of energy equal to the energy contained in a BARREL of crude oil or 5,800,000 Btu.

BASE LOAD -- The amount of electric power needed to be delivered at all times and all seasons.

BASE LOAD STATION -- A power generating station usually operated at a constant output to take all or part of the BASE LOAD of a system.

BENEFIT-COST RATIO (B/C) -- The ratio of the present value of the benefit (e.g. revenues from power sales) to the present worth of the project cost.

BOE -- See BARREL-OF-OIL EQUIVALENT.

BRITISH THERMAL UNIT (Btu) -- The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

BTU -- See BRITISH THERMAL UNIT (Btu).

BLM -- Bureau of Land Management.

CAPACITY -- The maximum power output or the load for which a generating unit, generating station, or other electrical apparatus is rated. Common units include kilovolt-ampere (kVA), KILOWATT (kW), and MEGAWATT (MW).

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*Capitalized terms indicate those defined elsewhere in this glossary.

CAPACITY FACTOR -- The ratio of the energy that a plant produces to the energy that would be produced if it were operated at full capacity throughout a given period, usually a year. Sometimes called the plant factor.

CAPACITY VALUE -- The part of the market value of electric power that is assigned to DEPENDABLE CAPACITY.

CAPITAL EXPENDITURES -- The construction cost of new facilities (additions, betterments, and replacements) and expenditures for the purchase or acquisition of existing utility plant facilities. Also called capital outlay.

CAPITAL OUTLAY -- See CAPITAL EXPENDITURES.

CAPITALIZED COST -- A method used to compare the costs of alternatives; it is equal to the sum of the initial costs and the present worth of annual payments, such as operation and maintenance costs.

CAPITAL RECOVERY -- See DEBT SERVICE.

CAPITAL RECOVERY FACTOR -- A factor used to convert an investment into an equivalent annual cost at a given interest rate for a specified period.

CFS -- CUBIC FEET PER SECOND.

CHECK STRUCTURE -- A structure where water flow is regulated and measured.

CIRCUIT BREAKER -- A switch that automatically opens to cut off an electric current when an abnormal condition occurs.

CIVIL WORKS -- All the works of a facility associated with plant structures, impounding channeling, and emergency release of water, etc.

COGENERATION -- The use waste heat from an industrial plant to drive turbine-generators for electricity generation. Also, the use of low-pressure exhaust steam from an electric generating plant to heat an industrial process or a space.

CUBIC FEET PER SECOND (cfs, ft^3/s) -- A flow equal to 646,317 gallons per day or 0.028317 cubic metres per second (m^3/s). Also called a SECOND FEET.

CRITICAL HEAD -- The HEAD at which the output of a turbine at full gate equals the NAME PLATE RATING of an associated GENERATOR.

DEMAND -- The rate at which electrical energy is delivered to a system, to part of a system, or to a piece of equipment; it is usually expressed in KILOWATTS, MEGAWATTS, etc.

DESIGN HEAD -- The HEAD at which the RUNNER of a turbine is designed to provide the highest efficiency.

DEBT SERVICE -- The principal and interest payments made on a debt used to finance a project. Also called capital recovery.

DEPENDABLE CAPACITY -- The minimum capacity available at any time during a study period. This value is generally determined by optimizing plant operation during the driest period when the least water is available.

DIRECT CURRENT (dc, DC) -- Electricity that flows continuously in one direction, as contrasted with ALTERNATING CURRENT.

DOE -- U. S. Department of Energy.

DRAFT TUBE -- A large tube that takes the water discharged from a TURBINE at a high velocity and reduces its velocity by enlarging the cross-section of the tube.

DUMP ENERGY -- Energy generated by water that cannot be stored or conserved and when such energy is beyond the need of the producing utility.

EFFICIENCY -- The ratio of the output to the input of energy or power, usually expressed as percentage.

EIS -- An Environmental Impact Statement prepared to satisfy the requirements of the Federal NATIONAL ENVIRONMENTAL POLICY ACT (NEPA).

ELECTRICAL ENERGY UNITS -- Common units used to measure electrical energy include KILOWATTHOURS (kWh) and GIGAWATTHOUR (GWh, million kWh). A 100-watt light bulb lit for ten hours will consume one KILOWATTHOUR (kWh) of electrical energy. A one-MEGAWATT generating unit will produce 1000 kWh if it runs for one hour at full CAPACITY.

END USER -- Any ultimate consumer of electricity or of any type of fossil fuel (petroleum, coal, natural gas).

ENERGY -- The capability of doing work which occurs in several forms such as potential, KINETIC, thermal, and nuclear energy. One form of energy may be changed to another; the kinetic energy of falling water can be used to drive a turbine where the energy is converted into mechanical energy which can drive a generator to produce ELECTRICAL ENERGY.

ENERGY DISSIPATER -- A device used to reduce water pressure to a level safe for certain uses.

EXTRA HIGH VOLTAGE (EHV) -- A term applied to voltage levels of transmission lines which are higher than the voltage levels commonly used. At present, electrical utilities consider EHV to be any voltage of 345,000 volts or higher. See ULTRAHIGH VOLTAGES.

FEASIBILITY STUDY -- An investigation to develop a project and definitively assess its desirability for implementation.

FEDERAL ENERGY REGULATORY COMMISSION (FERC) -- An agency in the U. S. Department of Energy, which licenses non-Federal hydropower projects and regulates the interstate transfer of electrical energy.

FIRM CAPACITY -- The load-carrying ability of a plant that would probably be available to supply energy for meeting LOAD at any time.

FIXED COSTS -- Costs associated with plant investment, including DEBT SERVICE, interim replacement, and insurance.

FLOW-DURATION CURVE -- A curve of flow values plotted in descending order of magnitude against time intervals, usually in percentages of a specified period. For example, the curve might show that over a period of a year, a river flows 500 CFS or more 10 percent of the time, and 100 CFS or more 80 percent of the time.

GENERATOR -- A machine that converts mechanical energy into ELECTRICAL ENERGY.

GIGAWATTHOUR (GWh) -- One million KILOWATTHOURS (kWh).

GROUND WATER -- The supply of water under the earth's surface, as contrasted to SURFACE WATER.

HEAD -- The difference in elevation between two water surfaces. In hydropower, the net head refers to the difference in elevation between the headwater surface above and the tailwater below a HYDROPOWER PLANT, minus friction losses.

HORSEPOWER (hp) -- The equivalent of 0.746 KILOWATT (kW).

HYDROPOWER PLANT -- An electric power plant in which the energy of falling water is converted into electricity by turning a turbine-generator unit. Also called a hydroelectric power plant, a hydroelectric plant, or simply a hydro plant.

IMPOUNDMENT -- A reservoir or artificial pond created behind a dam.

INCREMENTAL COST -- The additional cost incurred when generating an added amount of power.

INSTALLED CAPACITY -- The total of the CAPACITIES shown on the nameplates of the generating units in a HYDROPOWER PLANT.

INTERRUPTIBLE ENERGY -- Energy that can be curtailed at the supplier's discretion.

KILO (k) -- A prefix meaning one thousand.

KILOWATT (kW) -- One thousand watts (W) or 1.34 HORSEPOWER (hp).

KILOWATTHOUR (kWh) -- One thousand watthours (Wh) - the amount of ELECTRICAL ENERGY produced or consumed by a one-KILOWATT unit for one hour.

KINETIC ENERGY -- The energy of motion; the ability of an object to do work because of its motion.

LOAD -- The amount of power required at a given point or points in an electric system.

LOAD FACTOR -- The ratio of the average load to the maximum load during a given period.

LOW-HEAD HYDROPOWER -- Hydropower that operates with a head of 20 metres (66 feet) or less.

MARKET VALUE -- The value of power at the load center, as measured by the cost of procuring equivalent alternative power to the market.

MEGA (M) -- A prefix meaning one million.

MEGAWATT (MW) -- One thousand KILOWATTS (kW) or one million watts (W).

MILL -- One tenth of a cent or one thousandth of a dollar.

MGD -- Million gallons per day, equivalent to 1.457 CUBIC FEET PER SECOND (cfs).

NAMEPLATE RATING -- The full-load continuous rating of a GENERATOR or other electrical equipment under specified conditions as designated by the manufacturer, and written on the nameplate.

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) -- An act, passed in 1969, requiring that the environmental impact of most projects and programs be identified. Among its important provisions is one requiring a detailed statement of environmental impact of, and alternatives to, a project to be submitted to the federal government before the project can begin.

NON-FOSSIL ENERGY -- Energy from sources other than fossil; non-fossil energy sources include nuclear, wind, tide, biomass, geothermal, water, and solar sources.

NEGATIVE DECLARATION -- The document which satisfies the CEQA requirement if no significant environmental impacts would result from a project as determined by an initial study.

OFF-PEAK -- The time of day and week when the demand for electricity is low; see ON-PEAK.

ON-PEAK -- The time of day and week when demand for electricity in a region is high.

OUTAGE -- The period in which a facility is out of service.

OUTAGE, FORCED -- The shutdown of a facility for emergency reasons.

OUTAGE, SCHEDULED -- The shutdown of a facility for inspection or maintenance, as scheduled.

OUTPUT -- The amount of power or energy delivered from a piece of equipment, a station, or a system.

PEAKING UNIT -- An auxiliary electric power system that is used to supplement the power supply system during periods of peak demand for electricity. Peaking units are usually old, low cost, inefficient units having a high fuel cost, or hydroelectric units having low FIRM CAPACITY.

PENSTOCK -- See pressure pipe used to carry water to a TURBINE.

PLANT FACTOR -- See CAPACITY FACTOR.

PRELIMINARY PERMIT -- An initial permit issued by the FEDERAL ENERGY REGULATORY COMMISSION (FERC) for hydropower projects. The permit does not authorize construction, but during the permit's term of up to 36 months, the permittee is given the right of priority-of-application for a license while completing the necessary studies to determine the engineering and economic feasibility of the proposed project, the market for the power, and all other information necessary for inclusion in an application for license.

PSI -- A unit of pressure as measured in pounds per square inch.

PUMPED-STORAGE PLANT -- A HYDROPOWER PLANT which generates electricity during periods of high demand by using water previously pumped into a storage reservoir during periods of low demand. Pumped storage returns only about two-thirds of the electricity put into it, but it can be more economical than obtaining and operating additional generating PEAKING UNITS.

PURPA -- Public Utility Regulatory Policies Act of 1978. This act requires utilities to purchase power from and interconnect with a privately developed facility and mandates the state utility regulatory agency to set a "just and reasonable price".

QUADRILLION -- Equivalent to 1×10^{15}.

QUADRILLION BTU (Quad) -- An amount of energy equal to the heat value of 965 billion cubic feet of gas, 175 million barrels of oil (BOE), or 38 million tons of coal.

RECONNAISSANCE STUDY -- See APPRAISAL STUDY.

REHABILITATION -- The restoration of an abandoned power plant to produce energy.

RETROFITTING -- Furnishing a plant with new parts or equipment not purchased or available at the time of manufacture or construction. In hydropower development, the term may refer to the installation of electric generating components at existing water facilities to produce electricity.

RIPARIAN RIGHTS -- The rights of a land owner to the water on or bordering his property, including the right to prevent diversion or misuse of upstream water.

ROYALTY -- The portion of the proceeds paid to the title holder in exchange for exploitation of a property.

RPM -- Revolution per minute.

RUNOFF -- The portion of rainfall, melted snow or irrigation water that flows over the surface and ultimately reaches streams.

RUNNER -- The part of a TURBINE, consisting of blades on a wheel or hub, which is turned by the pressure of high-velocity water.

RUN-OF-THE-RIVER-PLANT -- A hydropower plant that uses the flow of a stream as it occurs with little or no reservoir capacity for storing water. Sometimes called a "STREAM FLOW" plant.

SBA -- Small Business Administration.

SECOND-FEET -- CUBIC FEET PER SECOND (cfs).

SEEPAGE -- Water that flows through the soil.

SERVICE AREA -- An area to which a utility system supplies electric service.

SINKING FUND-- A fund set up to accumulate a certain amount in the future by collecting a uniform series of payments.

SPILLWAY -- A passage used for running surplus water over or around a dam.

SPINNING RESERVE -- Generating capacity that is on the line in excess of the load on the system ready to carry additional electrical LOAD.

STANDBY SERVICE -- Service that is not normally used, but is available, in lieu of or as a supplement to, the usual source of supply.

STREAM FLOW -- The amount of water passing a given point in a stream or river in a given period, usually expressed in CUBIC FEET PER SECOND (cfs), or MILLION GALLONS PER DAY (mgd, MGD).

SUBSTATION -- An assemblage of equipment used to switch and/or change or regulate the voltage of electricity.

SURFACE WATER -- Water on the earth's surface that is exposed to the atmosphere such as rivers, lakes, oceans, as contrasted to GROUND WATER.

SURPLUS ENERGY -- Generated energy that is beyond the immediate needs of the producing system. This energy is usually sold on an interruptible basis.

SWITCHING STATION -- An assemblage of equipment used for the sole purpose of typing together two or more electric circuits through selectively arranged switches that permit a circuit to be disconnected in case of trouble or to change electric connections between circuits. A type of SUBSTATION.

TAILRACE -- The channel, downstream of the DRAFT TUBE, that carries the water discharged from the TURBINE.

THERM -- The equivalent of 100,000 BRITISH THERMAL UNITS (Btu).

THERMAL PLANT -- An electric generating plant which uses heat to produce electricity. Such plants may burn coal, gas, oil, biomass, or use nuclear energy to produce thermal energy.

TRANSFORMER -- A device used to change the voltage of ALTERNATING-CURRENT (AC) electricity.

TRANSMISSION -- The act or process of transporting ELECTRICAL ENERGY in bulk from a source or sources of supply to other principal parts of a system or to other utility systems.

TURBINE -- A machine in which the pressure or KINETIC ENERGY of flowing water is converted to mechanical energy which in turn can be converted to ELECTRICAL ENERGY by a GENERATOR.

ULTRAHIGH VOLTAGES (UHV) -- Voltages greater than 765,000 volts. See EXTRA HIGH VOLTAGE (EHV).

ULTRALOW HEAD --HEAD of up to 3 metres (9.8 feet).

USCE -- U. S. Army Corps of Engineers.

USGS -- U. S. Geological Survey.

WATERSHED -- The region draining into a stream.

WATER TABLE -- The upper limit or surface of the GROUNDWATER.

WATER TREATMENT -- The purification of water to ensure its potability or safety for disposal, or to permit alternative use or reuse.

WEIR -- A dam in a stream to raise, divert the water, or to regulate the flow.

WHEELING -- The transportation of electricity by an electric utility over its lines for another utility.

WICKET GATES -- Gates at the entrance of a turbine used to control water flow into a TURBINE.

WORKING CAPITAL -- The amount of cash or other liquid assets that a company must have on hand to meet the current costs of operations until it is reimbursed by its customers. Sometimes the term is used to mean the difference between current and accrued assets and current and accrued liabilities.

WPRS -- U. S. Water and Power Resources Service (formerly U. S. Bureau of Reclamation).

YIELD -- The amount of water which can be supplied from a reservoir or a water source in a specified period.